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ABSTRACT

One of five volumes intended to help teachers of mainstreamed handicapped children, the book presents 19 papers on science instruction. Papers address the issues of goals; prerequisites; approaches (cooperative, multisensory, and concept analysis); materials; barriers; and evaluation. The following titles and authors are included: "Science for the Handicapped--Can We Justify It?" (A. Scheinker, C. Coble); "Strategies in Science Instruction for Students with Special Learning Disabilities (Prompted by Piaget's Formulations)" (N. Adibe); "Metric Measurement for Blind Students" (F. Franks); "Mainstreaming Handicapped Students into Science Classrooms" (R. Johnson, D. Johnson); "Cooperative Goal Structures and the Mainstreaming of Handicapped Students" (M. Corrick); "Creativity for the Mentally Handicapped" (D. Daugs); "An Audio-Tactile Approach to Science Education for Visually Impaired Students" (R. Harris); "Chemistry Experiments for the Deaf Secondary Student--A Visual Approach" (R. Menchel); "The Man, the Child, and the Flower (Laboratory Science for the Handicapped Student--Teaching Mainstream Strategies)" (D. Hadary); "Concept Analysis--A Model for Teaching Basic Science Concepts to Intellectually Handicapped Students" (J. Cole, et al.); "The Visually Impaired High School Student Can See Her or His Progress in the Regular Science Classroom" (M. Ovnik); "Strategies for Stimulating Scientific Inquiry for All Students" (P. Welliver); "Multisensory Science Education--Meeting Special Challenges" (L. Malone, L. De Lucchi); "Using Science to Strengthen Communication Skills of Hearing Impaired Students" (D. Orlich, K. Black); "Science for the Developmentally Disabled" (J. Trotta); "Science for Deaf Students--Curriculum Suggestions for Grouped and Mainstreamed Programs" (J. Stolte, S. Smith); "Some Thoughts on Teaching Science to the Mentally Handicapped Secondary Student" (M. Mathias, R. Johnson); "Some Psychological Considerations in the Education of Blind Students" (E. Gough); and "Criterion-Referenced Testing and Prescriptive Instruction in the Science Classroom (H. Lang). (CL)

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Marshall E. Corrick, Jr., Editor

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Teaching Handicapped Students

SCIENCE

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The Editor

Marshall Corrick is a science instructor at Lincoln High School, Bloomington, Minnesota. His selections for this book represent materials which he feels are especially pertinent and practical for science classroom teachers.

Acknowledgment

"Concept Analysis: A Model for Teaching Basic Science Concepts to Intellectually Handicapped Students" by Jack T. Cole, Margie K. Kitano, and Lewis M. Brown is a revised version of "Rx: Concept Analysis" which appeared in the April 1978 issue of *Early Years*. It has been revised and reprinted here with the permission of the publisher of *Early Years*.

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FOREWORD

Prepared by the

NEA Committee on Education of the Handicapped

Public Law 94-142, The Education for All Handicapped Children Act, the major federal education legislation for providing a free appropriate education for all handicapped children, must be in compliance with Section 504 of the Rehabilitation Act of 1973. Part D of Section 504 states, in part:

> The quality of the educational services provided to handicapped students must be equal to that of the services provided to nonhandicapped students; thus, handicapped students' teachers must be trained in the instruction of persons with the handicap in question and *appropriate materials and equipment must be available.*

This federal regulation is supported by NEA policy. Point (e) of NEA Resolution 79-32, Education for All Handicapped Children, reads:

> The appropriateness of educational methods, materials, and supportive services must be determined in cooperation with classroom teachers.

In the context of federal education policy and NEA policy, members of the NEA Committee on Education of the Handicapped have reviewed *Teaching Handicapped Students Science*. Members of the Committee are teachers of English, social studies, mathematics, special education, and science, who teach both general and handicapped students in elementary and high school.

The Committee cannot emphasize too strongly the importance of teachers of regular and special education working together. The Committee would also like to urge both groups of educators to use these publications in teaching content areas to handicapped students. Members of the Committee were particularly pleased that teachers wrote these materials, in an effort to successfully teach the handicapped in the least restrictive environment. Because of their firsthand knowledge of proper teaching strategies, teachers are the best source of information to aid their colleagues.

The NEA supports P.L. 94-142 because the Association is committed to education processes which allow all students to become constructive, functioning members of their communities. To this end, when handicapped students are appropriately placed in classrooms with nonhandicapped students, teachers need instructional strategies which provide for individual learning differences. This is not new. However, most regular education teachers have not been trained, as mandated by law, in pre-service or in-service experiences to work with students with handicapping conditions. Teachers are eager to carry out the mandate of the law, but they may shy away from or even object to teaching these students because of this lack of training.

The so-called "mainstreamed" classroom presents new challenges to regular classroom teachers because of the added responsibility of teaching students with handicapping conditions. It is particularly important, therefore, to understand the student with a handicapping condition as a whole person in order to emphasize this commonality among all students.

NEA Committee on Education of the Handicapped

Georgia L. Gibson, Chairperson, Stratford, New Jersey; *Lee Betterman*, Mount Prospect, Illinois; *Eugenio del Valle*, Hato Rey, Puerto Rico; *Ruth D. Granich*, Bloomington, Indiana; *John Knapp*, Cleveland, Ohio; *Min Koblitz*, Scarsdale, New York; *James Rathbun*, Las Vegas, Nevada; *Ken Rosenbaum*, Louisville, Kentucky; *Ruth Watkins*, Raleigh, North Carolina.

INTRODUCTION

by Marshall Corrick

"Where am I supposed to go?"
"Can I start from where I am?"
"What routes can I take?"
"Must I use a particular vehicle?"
"What are the roadblocks?"
"How will I know when I have arrived?"

For any student on the road to an education, these are important questions to be answered. Recently science educators have been faced with the challenge of answering these questions for a new population, the handicapped

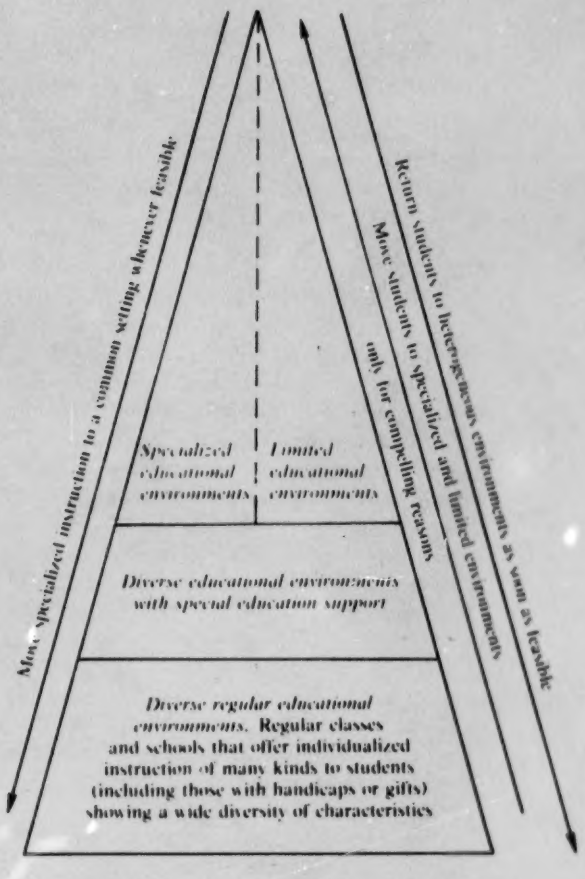
Before beginning a discussion of TEACHING HANDICAPPED STUDENTS SCIENCE, it may be well to offer definitions of several terms that appear throughout the book in relation to instruction of the handicapped.

1. *Disability*—A disability is a deficiency in a characteristic or condition indigenous to the individual that results in a low potential for success at activities dependent on that characteristic or condition. Individuals may have single or multiple disabilities. They may be disabled in some areas and gifted in others. A disability is a characteristic but not the character of a child.
2. *Handicap*—A handicap is a condition or characteristic that prevents an individual from functioning appropriately or at the level of expectation in a given situation or environment. These handicapping conditions may be physical, mental, perceptual, emotional, educational, motivational, social, or situational.
3. *Mainstreaming*—Mainstreaming is an educational placement procedure and process for children, based on the belief that each child should be educated in the least restrictive environment in which her or his educational and related needs can be satisfactorily met. Mainstreaming assumes a number of conditions: that children have a wide range of special education needs, varying greatly in intensity and duration; that there is a recognized continuum of educational settings that may, at a given time, be appropriate for an individual child's needs; that, to the maximum extent appropriate, children should be educated together; and that special classes, separate schooling, or removal of a child from education with other children should occur only when the child's educational and related needs are so intense that they cannot be satisfied when he or she is placed in an environment with other children, even with the provision of supplementary aids and services.
   a. *Least restrictive alternative/environment*—Least restrictive environment implies that, to the maximum extent appropriate, children are integrated in the regular educational environment. Special classes, separate schooling, or other removal of children from the regular classroom environment occurs only when (and then only to the extent necessary) the nature or severity of a handicapping condition is such that their education cannot be achieved satisfactorily in regular classes with the use of special education services.
   b. *Educational needs*—The educational needs of students are social, psychological, and physical, as well as academic. Mainstreaming may occur in all or only some of these areas of educational concern. For example, a student may be physically located in a mainstreamed school situation but isolated there socially and academically. Several kinds of mainstreaming are preferred over isolation whenever they are compatible with the students' developmental needs.
   c. *Continuum of educational settings*—The continuum of educational settings may be shown in two models. The prevailing or traditional model is place centered. The preferred model is person centered.

      In both models it is assumed that students should be removed from the mainstream only for limited and compelling reasons; that when in specialized and limited environments, their progress should be monitored carefully and regularly; and that they should be returned to the mainstream as soon as it is feasible.

      The preferred model, as indicated in the following diagram, proposes that (1) regular classes be made more educationally diverse, which would diminish the need to develop and use separate specialized educational environments, and (2) regular schools and classes have diversified staff and offer many forms of instructional programs so that a great variety of stu-

The Preferred Model For
The Continuum Of Educational Settings


Move specialized instruction to a common setting wherever feasible
Return students to heterogeneous environments as soon as feasible
Move students to specialized and limited environments only for compelling reasons
Specialized educational environments
Limited educational environments
Diverse educational environments with special education support
Diverse regular educational environments. Regular classes and schools that offer individualized instruction of many kinds to students (including those with handicaps or gifts) showing a wide diversity of characteristics

dents can be accommodated, and with good results.

This continuum of educational settings puts first priority on moving various forms of special instruction into the regular classroom structures rather than moving the students out to the specialized service. Some separate specialized and limited educational environments would remain, however.

Because of many factors, the questions raised at the beginning of this "Introduction" are not simple to answer. The answers given thus far to the handicapped in the form of IEPs (Individualized Education Programs) have often been vague and general. Yet, we must find specific and effective answers to these questions, and the reflection, evaluation, stimulation, and, often, frustration now being experienced in educational circles could result in a new conceptualization of science education which has far-reaching implications not only for the handicapped, but also for all students in our schools, no matter what their abilities or disabilities.

This book is, in a very real sense, a reflection of that stimulation, evaluation, and frustration. It is not intended to be a carefully organized progression of ideas leading to a final conceptualization of an effective mainstreaming model, and while I, as editor, have attempted some organization and structure, as indicated in the content sections, it must be kept in mind that this structure has been imposed after the fact and that any given chapter may overlap several areas of approach.

The first section of the book relates to *goals*. What goals do we expect the students to achieve as a result of participating in science classes? Should these goals be the same for all students? Which goals are the most important?

One approach to developing science strategies for the handicapped has focused on the examination and modification of goals to meet the needs of the handicapped child. This approach has been used most extensively in the development of materials for the mentally handicapped. In the first chapter Alan Sheinker and Charles R. Coble examine the legislative and social backgrounds of mainstreaming, the challenge of mainstreaming in science, the formulation of appropriate goals for the handicapped, and some of the programs and materials available to teachers who face the responsibility of teaching the handicapped in a mainstream classroom.

Section Two considers the *prerequisites* for education of the handicapped in the mainstream classroom. Educators have long been aware that knowledge builds upon knowledge, skill upon skill, and in recent years there has been much emphasis on defining goals and objectives—what students should be able to do when the task is finished or the course completed. However, little attention has been given to determining what knowledge or skill is required of the students *in order to begin*, which is an area of extreme importance, especially to the handicapped who may have been barred from developing prerequisite skills in the past.

In Chapter 2 Nasrine Adibe examines the concepts and formulations of Piaget and their implications for the teaching of science to both the regular and the handicapped student in the mainstream classroom. Along with the developmental stages, Adibe examines the clinical methods of Piaget and the nature of intelligence, learning, and motivation, with practical applications of these concepts made to the mainstream science classroom.

In Chapter 3 Frank L. Franks examines specific skills prerequisite to the development of measuring skills and outlines an approach for developing these skills in the blind.

Many *approaches* to teaching the handicapped are available to accommodate all of their learning styles. In addition, existing delivery systems can be modified to provide more flexibility in their instruction. Section Three deals with various teaching techniques—really the main thrust of this book. For convenience, these various approaches to teaching the handicapped have been subdivided in four general categories.

The Cooperative Approach. Because its use of heterogeneous cooperative groups provides for the integration of the handicapped student into the mainstream classroom socially and academically as well as physically, the cooperative approach is one of the most innovative and powerful techniques available.

Roger T. Johnson and David W. Johnson explore the meaning and purpose of mainstreaming and the value of cooperative groups as the goal structure within which this purpose can best be accomplished in Chapter 4.

In Chapter 5 Marshall Corrick examines practical techniques for the effective use of cooperative groups in a heterogeneous mainstream science class.

Finally, in Chapter 6 Donald R. Daugs describes the teaching of creativity to the mentally handicapped student in a mainstream cooperative setting.

The Multisensory Approach. The multisensory approach to science teaching has great value for the physically handicapped child who has been deprived of one of his or her senses. It has value almost as great, however, for the student with weak learning modalities but with no physical impairment. Some students learn best by seeing, some by hearing; some have to touch and manipulate objects in order to learn; but almost all students learn better if they can do all three.

Randall Harris writes in Chapter 7 of an audio-tactile approach, especially useful in instructing the visually impaired, but also applicable to teaching sighted individuals with weak visual learning modalities.

In Chapter 8 Robert S. Menchel discusses a chemistry program developed for the deaf with emphasis on visual learning. In addition to overcoming the handicapping condition resulting from loss of hearing, the program deals with the experiential handicaps resulting from previous lack of exposure to science.

Chapter 9, written by Doris E. Hadary, illustrates how the multisensory approach can be combined with creativity and art to produce what might be called the *total experience approach* for both the handicapped and the regular student.

The Concept Analysis Approach. Jack T. Cole, Margie K. Kitano, and Lewis M. Brown develop the concept analysis model in a clear and meaningful way in Chapter 10. Further, they offer it as a viable approach to the problem of successfully teaching abstract science concepts to the intellectually handicapped student (as well as the regular student) because this technique fosters concept formation, thinking ability, logical deduction, and creative problem solving.

The Team Approach. In an application of the team approach in Chapter 11, Mary Ann Ovnik describes a mainstream science program in which the regular classroom teacher and the special resource teacher work together with the student and her or his parents to produce and modify a data-based science program, enabling blind as well as sighted students to "see" their progress.

Over the past several years, many teachers' curricular groups and commercial publishing companies have made an effort to address the problem of appropriate material for the handicapped student. Four examples of this effort are included in the discussion of *learning materials* in Section Four.

In Chapter 12, Paul W. Welliver examines a set of four components and five strategies found in *Investigative Science in Elementary Education* by D. Alfke, A. A. Shrigley, and Paul W. Welliver that contributes to a successful science program for handicapped and regular students.

Chapter 13, written by Larry Malone and Linda De Lucchi, describes the multisensory materials produced for the visually impaired in the SAVI program. They have found that such a carefully prepared program results in the growth of student self-esteem and confidence. Within the context of the multisensory experience, the students' handicaps are circumvented or "neutralized," resulting in success which produces a "good feeling" that often carries over into other aspects of life.

Prepared by Donald C. Orlich and Kathleen M. R. Black, Chapter 14 describes a program using SCIS materials with hearing impaired students to strengthen both their science and their communication skills.

In the final chapter in this section, Chapter 15, Judith J. Trotta examines a variety of materials that may be used with the developmentally handicapped child including SCIS, *Me Now*, and *Me and My Environment*. The author finds that to survive in the real world, all children must become scientifically literate, and that this concept applies especially to the handicapped if the gap which already exists developmentally between them and normal children is not to be allowed to widen.

Also crucial is an examination of the *barriers* to the education of the handicapped—the topic of consideration of Section Five. Which barriers can be negotiated? Which can be circumvented? Which can and should be removed?

Handicapping conditions are not indigenous to the individual but result from the interaction of a disability with a barrier. As long as no barriers exist, the handicapped student can function quite appropriately. Some of the barriers encountered by the handicapped may be natural; however, few are insurmountable. Others are

imposed by the system and can often be circumvented or removed. The barriers most difficult to overcome are psychological and attitudinal barriers that have little foundation in the nature of the disability itself.

Chapter 16, written by Joanne B. Stolte and Shirley C. Smith, reviews the special needs of and barriers faced by deaf students, both academically and in careers and career exploration. The areas of language development, projective and imaginative thinking, estimation skills, and inquiry skills are explored, as are the barriers resulting from negative societal expectations for deaf individuals.

In Chapter 17, Marilynne Mathias and Robert A. Johnson examine the barriers encountered by mentally handicapped students. The authors provide suggestions for dealing with such problem areas as low reading level, limited language skills, short attention span, and low self-esteem. Among the available techniques they present are the provision of more precise teaching, the use of better questioning techniques, and the adaptation of the instructional program to accommodate individual differences.

In the final chapter on barriers, Chapter 18, Elva R. Gough discusses some of the characteristics of and barriers for blind students. Piagetian developmental theory is used to demonstrate the need for concrete operational activities, emphasizing the fact that blind students possess the same intellectual potentials as do sighted students, although this potential reaches maturity at a slower rate.

One of the most troublesome areas for educators—and the central topic of Section Six—is *evaluation*. How handicapped students should be evaluated, the selection of criteria by which to measure the education of the handicapped, and the definition of educational success are all important concerns that are examined by Harry G. Lang in Chapter 19. Lang finds Public Law 94-142 to be a call for recognition of the usefulness of both criterion-referenced and norm-referenced evaluation methods in their most appropriate contexts.

As mentioned previously, the goal here is not the formulation of a mainstreaming model. The articles presented constitute a means to an end rather than the end itself. The viewpoints expressed are divergent rather than convergent in an effort to expand the scope of thinking for the individual science teacher through exposure to numerous possible approaches. Convergence can come only as the various options are amplified, modified, or rejected in the context of a particular perspective and circumstance as educators attempt to merge theory and practice in a restructuring of the eduational system that will benefit all students.

1. SCIENCE FOR THE HANDICAPPED: CAN WE JUSTIFY IT?

by Alan Sheinker and Charles R. Coble

The authors examine the legislative and social backgrounds of mainstreaming, the challenge of mainstreaming in science, the formulation of appropriate goals for the handicapped, and some of the programs and materials available to teachers who face the responsibility of teaching the handicapped in a mainstream classroom. *Alan Sheinker is Resource Specialist, Region V Board of Cooperative Educational Services and Teton County Schools, Jackson Hole, Wyoming. Charles R. Coble is Associate Professor in the Department of Science Education, East Carolina University, Greenville, North Carolina.*

A review of federal legislation affecting handicapped persons indicates that federal involvement has increased dramatically during the past 20 years. Approximately one-third of the 195 relevant laws passed between 1827 and 1975 were enacted between 1970 and 1975. (11) Two laws stand out as the culmination of legislation and litigation that will ensure the handicapped their proper place in American education: The Education for All Handicapped Children Act (Public Law 94-142) and Section 504 of the Rehabilitation Act of 1973.

Among the provisions of PL 94-142 are a free, appropriate public education for handicapped persons aged 3 to 18 by September 1, 1978, and aged 3 to 21 by September 1, 1980. It provides educational placement in the least restrictive alternative, implying that the handicapped should be educated with the nonhandicapped to the maximum extent possible. To ensure this, PL 94-142 has included legal sanctions for the Individualized Education Program (IEP). Specifically, the IEP must include the following:

> (A) A statement of the child's present levels of educational performance;
> (B) A statement of annual goals, including short-term instructional objectives;
> (C) A statement of the specific special education and related services to be provided to the child, and the extent to which the child will be able to participate in the regular classroom;
> (D) The projected dates for initiation of services and the anticipated duration of the services; and
> (E) Appropriate objective criteria and evaluation procedures and schedules for determining, on at least an annual basis, whether the short-term instructional objectives are being achieved. (16, Sec. 121a.346)

Thus, the IEP is a detailed, comprehensive plan that cannot be thought of as a static, one-time contrivance. (5) Its development is a dynamic process requiring a significant amount of time and effort on the part of the teacher. Each of the IEP components requires accurate and reliable assessment procedures based on learning disability principles. (17) When properly utilized, the IEP can facilitate learning, ensure student progress, and ensure accountability. (13) Those interested in more information on IEP's are encouraged to read "An Approach to Operationalizing the IEP" (5) and *Developing and Implementing Individual Education Programs* (14).

The second significant piece of legislation to be discussed, Section 504 of the Rehabilitation Act of 1973, is a civil rights law which specifically protects the rights of handicapped children and adults. It states:

> No otherwise qualified handicapped individual shall, solely by reason of his handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving federal assistance. (15, Sec. 45.84)

Referring to Section 504 and PL 94-142, Edward Martin summarized their implications as follows:

> Read together, these two statutes and their implementing regulations require that by September 1, 1978, each handicapped child must be provided all services necessary to meet his/her special education and related needs. (8, p. 5)

One must accept the premise that handicapped students have needs similar to those of nonhandicapped students. (12) They need an enriched, supportive environment in order to develop their mental and physical capa-

bilities. They need to acquire and expand their potential language skills in reading, writing, listening, and oral communication. They need to develop feelings of accomplishment and a positive self-image. They need to develop skills in coping with the problems that will continue to confront them in an increasingly complex and scientific world. Good, activity-oriented science instruction helps nonhandicapped learners meet these needs, and similar instruction is as good or better for handicapped students.

Educational goals for handicapped students do not differ from those for the nonhandicapped. The Educational Policies Commission (2) of the National Education Association lists the following goals for all students:

1. Achievement of self-realization
2. Development of proper human relationships
3. Attainment of economic efficiency
4. Assumption of civic responsiblity

Most educators agree that the main goals of science education for the handicapped are also consistent with those for all other students:

1. To know some of the basic facts, concepts, generalizations, and principles in the life, earth, physical, and environmental sciences.
2. To develop primary and higher level process skills to help in problem solving.
3. To develop student interest in and appreciation for the world around them.

In the past, educators have held some false assumptions about the handicapped, some of which were as follows:

1. They are not capable of learning science—it is too difficult for them.
2. They are not interested in science.
3. They cannot manipulate science equipment.

However, these assumptions greatly underestimate the abilities of the handicapped. Numerous projects and research studies have indicated that the handicapped—

1. Can learn science concepts.
2. Are interested in science and science activities.
3. Can develop problem-solving skills in science.
4. Can manipulate scientific equipment.
5. Can help establish desirable work habits that help with daily life experiences.

If science instruction places undue reliance on reading and lectures, then many handicapped students will experience academic failure. Science content can present some major problems with regard to understanding scientific vocabulary, comprehending abstract concepts, and understanding complex and lengthy sentences.

Students who are visually impaired, auditorily impaired, learning disabled, or mentally retarded may have a preferred learning style. Some learn best through visual experiences; others through auditory, tactile, or kinesthetic channels. A way to help handicapped (and all other) students learn science is to plan activities that focus on their learning strengths. Science activities that allow for a variety of sensory experiences with concrete materials can better accommodate the different learning styles of students.

Rita and Kenneth Dunn have developed the Learning Style Inventory (LSI), an instrument used to diagnose a student's preferred learning style. The LSI is designed for students in grades 3–12 and can be administered in approximately 30 minutes. Some sample items are:

I really like to mold things with my hands.
The things I learn best are the things I read.
The things I learn best are the things I hear.
It's hard for me to sit in one place for a long time.
I really like to do experiments.
I have to be reminded often to do something!
I like to study with one or two friends.
Noise bothers me when I am studying. (1, pp. 401–404)

Upon reviewing what is known about learning styles and other characteristics of the handicapped, it becomes apparent that the following general techniques for teaching science to handicapped students can be applied in the mainstreamed classes:

1. Rely as much as possible on all of the senses. Depending on the types of handicap of those involved, teachers will want to provide firsthand experiences that will allow students to see, feel, hear, and smell what is being studied as much as possible.
2. Essential content questions and activity directions should be available in written and auditory forms. Tape-recording your class discussions as they occur will allow a second-chance opportunity for some students.
3. Good organization and clear directions are particularly helpful to the handicapped.

Some studies suggest that teachers feel that academically and emotionally handicapped students pose more problems in terms of mainstreaming than do students whose handicaps are primarily physical and sensory. (4) Considering this, and the fact that educable mentally handicapped (EMH) students constitute the largest population of handicapped students that most teachers will

teach, it is appropriate to examine this group in more detail.

Thomas P. Lombardi and Patrick Balch have summarized the common learning characteristics related to the mentally handicapped. As a group they have—

1. Generally slower than average rates of learning
2. Difficulty in understanding abstractions and relationships
3. Short attention spans
4. Deflated self-concepts
5. Language inadequacies
6. Poor visual-motor coordination
7. Limited academic achievement (7, p. 20)

These characteristics imply that teachers need to actively involve students with science experiences that are directly related to the world of the learner. Lessons need to be divided into smaller, step-by-step units and more time must be allowed for students to internalize their learning. The use of scientific and technical vocabulary should be kept to a minimum. Authors of the Biological Science Curriculum Study (BSCS) programs for the mentally handicapped have identified six "Principles of Presentation" for EMH students, based on their learning characteristics:

1. The tasks should be uncomplicated.
2. The tasks should be brief.
3. The tasks should be sequentially presented.
4. Each learning task should be the kind where success is possible.
5. Overlearning must be built into the lesson.
6. Learning tasks should be applied to objects, problems and situations. (10, p. 37)

These principles are applied in three BSCS programs—*Me Now, Me and My Environment*, and *Me in the Future*—developed with funds from the Bureau of Education for the Handicapped of the U.S. Office of Education.

Me Now presents life science materials to EMH students with a chronological age of 11 to 13 years. The structure and function of the human body is detailed in the program in four instructional units: (1) Digestion and Circulation; (2) Respiration and Body Water; (3) Movement; Support and Sensory Perception; and (4) Growth and Development. The program utilizes filmloops, slides, pictures, worksheets, and many manipulative materials. (10, pp. 35-36)

Me and My Environment focuses on environmental science for 13- to 16-year-old EMH students. The format is similar to *Me Now*. There are no student texts; however, comprehensive teachers' manuals include instructions for preparation and presentation of lessons. *Me and My Environment* is divided into five units: (1) Exploring My Environment; (2) Me as an Environment; (3) Energy Relations in My Environment; (4) Transfer and Cycling of Material in My Environment; and (5) Water and Air in My Environment. (10, p. 36)

The third program in the BSCS series, *Me in the Future*, combines science and career education. Activities are geared toward teaching the processes of critical thinking and independent action. Simulation exercises are provided to develop an understanding of three major areas of study: (1) Science and Vocations; (2) Science and Leisure; and (3) Science and Daily Living Skills. (9)

Other science curriculums have been developed for use with visually impaired students. For example, *Science Activities for the Visually Impaired* (SAVI) was developed by the staff of the Lawrence Hall of Science at the University of California at Berkeley. The SAVI program introduces students to key concepts in the physical and life sciences in a multisensory way. Visually impaired students between 9 and 12 years of age are challenged to put their senses to work making predictions, carrying out experiments, and drawing conclusions from the outcomes. SAVI activities are organized into topical clusters called modules. Presently the following modules have been field tested: (1) *The Structure of Life*; (2) *Scientific Reasoning*; (3) *Communication*; (4) *Environments*; (5) *Mixtures and Solutions*; (6) *Measurement*; (7) *Environmental Energy*; (8) *Kitchen Interactions*; *and* (9) *Magnetism and Electricity*. (6)

By combining the efforts of both science and special education teachers, we can provide handicapped students with the *most appropriate* education in the *least restrictive* environment necessary to achieve their maximum potential.

REFERENCES

1. Dunn, Rita, and Dunn, Kenneth. *Teaching Students Through Their Individual Learning Styles: A Practical Approach*. Reston, Va.: Reston Publishing Company, 1978.
2. Educational Policies Commission. *The Purposes of Education in American Democracy*. Washington, D.C.: National Education Association, 1938.
3. Hadary, Doris E., and others. "Interaction and Creation Through Laboratory Science and Art for Special Children." *Science and Children* 13(6): 31-33; 1976.
4. Hoffman, Edward; West, Terry; and Bates, Percy. *Science Education* 62(1): 11-17; 1978.
5. Hudson, Floyd G., and Graham, Steve. "An Approach to Operationalizing the IEP." *Learning Disability Quarterly* 1(1): 13-32; 1978.
6. Laetsch, W.M., and Their, Herbert D. *Introducing SAVI: Science Activities for the Visually Impaired*. Berkeley, Calif.: Lawrence Hall of Science, 1979.
7. Lombardi, Thomas P., and Balch, Patrick. "Science

Experiences and the Mentally Retarded." *Science and Children* 13(6): 20; 1976.

8. Martin, Edward. *Insight* 12: December 19, 1977.

9. *Me in the Future*. Biological Science Curriculum Study. *BSCS Newsletter* 66: February 1977.

10. Menhusen, Bernadette R., and Gromme, Roy O. "Science for Handicapped Children—Why?" *Science and Children* 13(6): 35-37; 1976.

11. Meyen, Edward L. *Exceptional Children and Youth: An Introduction*. Denver: Love, 1979.

12. Post, Thomas R.; Humphreys, Alan H.; and Pearson, Mickey. "Laboratory-based Mathematics and Science for the Handicapped Child." *Science and Children* 13(6): 41-43; 1976.

13. Turnbull, Ann P., and Schulz, Jane B. *Mainstreaming Handicapped Students: A Guide for the Classroom Teacher*. Boston: Allyn Bacon, 1979.

14. Turnbull, Ann P.; Strickland, Bonnie B.; and Brantley, John C. *Developing and Implementing Individual Education Programs*. Columbus, Ohio: Charles Merrill, 1978.

15. U.S. Department of Health, Education, and Welfare. *Federal Register* (Part IV) 42(86): May 4, 1977.

16. _____ . *Federal Register* (Part IV) 42(163): August 23, 1977.

17. Wallace, Gerald, and McLoughlin, James A. *Learning Disabilities: Concepts and Characteristics*. Second edition. Columbus, Ohio: Charles Merrill, 1979.

2. STRATEGIES IN SCIENCE INSTRUCTION FOR STUDENTS WITH SPECIAL LEARNING DISABILITIES (PROMPTED BY PIAGET'S FORMULATIONS)

by Nasrine Adibe

The concepts and formulations of Piaget and their implications for the teaching of science to both the nonhandicapped and the handicapped student in the mainstream classroom are examined. The author is Associate Professor, School of Education, Department of Curriculum and Instruction, C. W. Post Center, Long Island University, Brookville, New York.

INTRODUCTION

Public Law 94-142, the Education for All Handicapped Children Act, signed in November 1975, required that, by October 1977, each state identify children with specific learning disabilities and provide them with appropriate programs and services. This legislation has resulted in confusion among educators, legislators, medical professionals, and parents because the term *specific learning disabilities* is vaguely defined. Its definition refers to symptoms and manifestations, the nature, cause, severity, and treatment of which have yet to be better understood.

Specific learning disabilities is not a new term. It was first suggested by Samuel A. Kirk to describe a heterogeneous group of children including those labeled as aphasic, brain-injured, dyslexic, and perceptually handicapped. (9) Parents of these children welcomed the new label as being less derogatory than previous labels. However, the new term *learning disability* did not provide any new insight for educators; nor did it provide the information needed to identify the symptoms, assess their degree of severity, and determine what educational programs would best meet the needs of learners in this category.

It is true that we have had children with such symptoms for generations; we still may not understand their problems. This explains the confusion, frustration, and fears that the signing of PL 94-142 has generated. However, the signing of this law has also stimulated research and challenged educators to assist these youngsters to develop to their full potential. It has focused attention on students who have learning problems, regardless of the medical and/or psychological diagnosis. As educators, we no longer can ignore or dare to neglect such students.

Meanwhile, we have to admit that at present, several years after the signing of PL 94-142, the confusion related to the field of specific learning disabilities has not diminished. The definition is still vague. The criteria used to identify children with specific learning disabilities exclude those who have learning problems related primarily to either one or a combination of the following: visual, hearing, and motor disabilities; mental retardation and emotional disabilities; and environmental, cultural, and economic factors. The various guidelines used to identify children with learning disabilities are not sophisticated enough to be reliable. The same child has been diagnosed—depending upon the method used and its interpretation—as dyslexic, hyperkinetic, neurologically handicapped, learning disabled, educationally or perceptually handicapped, and brain damaged. (4) Other children have been labeled as learning disabled for such naive reasons as the fact that they tease the family cat, have nightmares, dislike to date girls, are disrespectful, are aggressive, and/or wear long hair. (4) Because of these nebulous criteria, it is difficult to determine the number of children affected by learning problems who can be categorized as having specific learning disabilities. (10) However, in 1976, this number was estimated to be 2-10% of the school-aged population. (20) Whatever the percentage, the important issue is that there are children with learning problems whom we cannot ignore anymore.

Children who are diagnosed as being learning disabled are now believed to have a greater potential for achievement than was formerly recognized. In the past children with learning disabilities were deprived of science activities. Those severely disabled enough to be in special programs were taught by teachers whose science backgrounds were limited, and those in regular classrooms were often neglected by science teachers who did not consider them "science material." Yet some scientists

and a number of college students who are now science majors have had learning problems during some phase of their schooling. This, together with experiences reported by science teachers who have worked with students in this category, provides data indicating that such youngsters *are* capable of handling science concepts. Furthermore, engaging them in appropriate science activities can remediate some of their learning problems. (5) Through my personal experiences, working directly with learners in this group, and through interaction with teachers trained to use certain strategies based on Piagetian findings, I have seen convincing evidence that these learners are capable of handling science concepts. Science disciplines are rich in content and in activities that enhance observation skills, challenge perceptual errors, develop the skills required for logical thinking, and increase attention span.

Creative and sensitive teachers who have empathy with their students with learning problems and who understand the conceptual structure of the scientific disciplines have had little problem in assisting these learning disabled students in experiencing, understanding, and developing knowledge and skills in science. Unfortunately, few teachers in the American school system are able to employ this approach because the emphasis is on narrow specialization and factual knowledge, and because the many details unrelated to science teaching that science teachers are burdened with during the school day leave very little time to develop and implement special activities that will assist students in overcoming their specific barriers to science learning.

Sensitizing teachers to students' cognitive levels, as well as raising their consciousness in regard to the crucial need for all of today's youth to be scientifically literate and knowledgeable, is an urgent need. I find that by understanding Piaget's work science teachers will become sensitized to their students' cognitive state. Piaget's work has given me some interesting insights into the complex and mysterious working of the human brain. Other educators have had similar reactions. After becoming familiar with Piaget's work, teachers can never again see their students or continue teaching in the same way as they did. G.A. Helmore explains this effect as "taking the top off the child's head and watching the wheels go round." (7, p. vii) Teachers become sensitized not only to their students' mental processes but also to their own mental processes. They become sensitive to real understanding of concepts by learners as opposed to their memorization of facts. They become more receptive to epistemological views of science. They re-examine their traditional views regarding intelligence, experience, and maturity. They become more selective of the instructional strategies they use in their classes. They develop questioning skills that stimulate heuristic inquiry from students. Their teaching styles become more flexible, and they themselves become more creative in improvising and using novel instructional materials and methods.

It is unfortunate that only a few teachers understand Piaget's work beyond his formulation of the cognitive developmental stages. This is only one dimension of Piaget's many findings. His research on the genesis of intelligence and the development of knowledge within the individual (ontogeny) as related to the increase of knowledge in society (phylogeny) has spanned over half a century. As important as the theory of developmental stages of intellectual maturity is, when this single aspect of Piaget's many formulations is taken out of the context of the whole, it can be misinterpreted, as it has been, and misimplemented, as it has often been. Piaget's method and his theories on learning, intellectual maturation, and language development can provide insight and information for science teachers as they attempt to devise and implement strategies in science instruction for students with special learning disabilities. The remainder of this chapter will examine selected ideas from Piaget's formulation that are applicable to such instruction.

PIAGET'S CLINICAL METHOD

Synoptic Exposé

The method Piaget has used to explore the development of intelligence from infancy to adulthood is ingenuously simple. It involves observing subjects as they react to a manipulative task and listening to their remarks, questions, or responses to questions. Piaget in these tasks does not look for specific correct answers. To Piaget, the errors his subjects make are just as revealing of his subjects' thought processes as are their correct actions or correct answers. As Freud has gained insight into the working of the mysterious brain in the affective field by observing his patients' slips of the tongue, so has Piaget collected valuable information on the working of the brain in the intellectual field by analyzing the mistakes and the absurd sayings of his subjects. Teachers who have tried to simulate this technique have found that their own questioning techniques improve and that they become more aware of their own thinking processes, as well as of those of their students. However, the success of this approach depends on the teacher's questioning and listening skills.

Implications

Diagnosing Students' Thinking. Most teachers are busy correcting their students' errors, giving little thought to what an error indicates. Analysis of students' errors can reveal students' thinking processes,

their logic, and their past experiences—an effective diagnostic tool for teachers at all levels and an especially vital one when dealing with youngsters who have special learning problems. Few science teachers can realize the various difficulties students with learning problems encounter when grappling with science content. By simulating Piaget's clinical method—confronting learners with a question and/or a task, listening to their questions, and observing their actions in a nonthreatening environment—teachers will be sensitized to the thought processes of their students.

Instead of depending solely on written tests to evaluate students, present the class with a situation or a problem, the solution to which requires familiarity with certain concepts. To illustrate: Instead of asking students to define the three states of matter, provide them with concrete examples of various solids, liquids, and gases, and ask them to classify these according to the appropriate category. At another level, assume that the intent is to assess the students' understanding of the concept that air is all around us; instead of posing the classical question, "Where is air?" ask specific questions such as, "Is there air under the table?" or "Inside this box?" or "In that bottle?" On the topic of gravity, provide the students with various objects of different weights and sizes, and let them predict which object will fall to the ground first when dropped at the same time and from the same height as one of the other objects selected as the control.

Assessing the Effectiveness of Teacher Strategies. Analyzing student errors can also provide information about the effectiveness of the strategies a teacher uses in instruction. Students' errors are often caused by faulty sequencing of content, by overdramatization of an application of a concept, by use of words and expressions not in the students' vocabulary, or by introduction of new content with little attention to students' previous experiences and knowledge. My experiences in teaching photosynthesis will serve as an example. The same student errors on tests related to photosynthesis and other plant functions recurred year after year. The students perceived that photosynthesis is the reverse of respiration; that respiration takes place only at night and that photosynthesis takes place only during the day. After several attempts to help students avoid such misconceptions, I found the answer lay in changing the sequence in which the topics were taught. Instead of teaching students the chemical formula for photosynthesis and showing them that the chemical formula for respiration is the same but that the process is reversed (as I had taught it in the past), I taught photosynthesis and its formula with no reference to respiration. I then taught respiration with its formula on another occasion weeks later. Student errors on this specific topic were greatly reduced.

INTELLIGENCE AND LEARNING

Synoptic Exposé

Piaget views intelligence as an adaptive behavior that allows the individual to cope more effectively with his/her environment. He uses models from biology to describe intelligence and learning. He explains adaptation as an inherent need for an organism to be in a state of equilibrium. Inevitably, the organism's state of equilibrium is disturbed either by the internal needs of the organism that must be satisfied or by the external demands imposed by changes in the environment. Adaptation to new conditions involves an active restructuring and accommodation to the environment on the part of the organism. This may result in a lasting alteration of form or structure. Equilibrium, the self-regulatory process underlying a biological organism, is achieved through the processes of accommodation and assimilation which are defined below.

Accommodation is the immediate and overt response to environmental demands. This entails change in the intellectual structures or schemes.

A *scheme* is what is generalizable in a given action. Schemes are coordinated among themselves in higher-order structures. Scheme is distinguished from schema in that *schema* is related to representational or figurative accommodations while *scheme* is related to operative accommodations.

A child is in a state of equilibrium when he/she has assembled all the pieces of a jigsaw puzzle to make the picture on the cover of the box. Suddenly a design in the picture catches his/her eye. Neither the color nor the shape of the design corresponds with what the child has on the completed puzzle. He/she is disequilibrated and must adapt to the new situation. In this case the child could very likely begin reorganizing the pieces of the jigsaw puzzle to match the picture on the box exactly. This is the process of accommodation. When he/she successfully completes the puzzle, a new state of equilibrium is reached. The child who has assimilated the skill or knowledge required for the new challenge emerges from such an experience with new structures or schemes that make him/her a cognitively richer individual.

Assimilation is the internal shaping of experience and the incorporating of the newly acquired experience into existing schemes. Assimilation, then, involves both restructuring one's experience and reinventing personal knowledge that becomes a part of the individual.

The concept of equilibration is central to Piaget's theory of acquisition of knowledge. He attributes acceleration of intellectual growth to the "dynamic progressive equilibration." In Piaget's words:

> The moment the equilibrium is reached on a point, structure is integrated into a new system being formed, until there is a new

equilibrium ever more stable and of an ever more extending field. (11, p. 60)

In addition to equilibrium, Piaget recognizes three other factors that influence the course of intellectual development and the acquisition of knowledge. They are:

1. *Heredity*, which accounts for the potential ability of an individual to mature through the various developmental stages.
2. *Physical experience*—"the action upon objects." This includes not only motor manipulation but also perceptual exploration and judgment.
3. *Social transmission*, which includes schooling, and the child's interaction with adults as well as with his/her peers.

Implications

Learning, according to Piaget, is an intellectual as well as an affective activity by which a person responds to environmental stimuli by organizing his/her existing experiences and weaving them into the new experience. This is a unique act of creation on the part of each individual. Therefore, the ability to respond to and organize new stimuli or new knowledge is highly dependent on the individual learner's previous knowledge and experiences and on what he/she is able to retrieve from this bank of knowledge and experiences that will enable him/her to find a state of equilibrium. Looking at learning from this point of view has definite implications when considering the many dimensions of teaching science to youngsters with learning disabilities.

Sensitizing Teachers. According to Piaget's theory of learning, it is imperative that the teacher determine students' *learning readiness*. A student is ready to learn a particular concept only when the particular scheme has been acquired—in other words, when the student has become familiar with the prerequisite concepts and skills. Since conventional intelligence tests and other diagnostic tests do not provide the teacher with the information required for this type of teaching, it becomes necessary to sensitize science teachers not to depend on the diagnoses and the labels that accompany the learning disabled students as they are mainstreamed. These diagnoses and labels are only an indication that the particular student has or has had some barriers to learning. It is important that science teachers use some diagnostic tools of their own. Science teachers can be sensitized to the perceptual flaws that may exist, trained in the skills needed to apply Piaget's "clinical method," and provided with ideas that will assist them in making individual diagnoses of students, without neglecting and taking time from the other students in class, so they will be providing real assistance to students with learning problems.

In addition to such techniques as analyzing student errors, confronting students with problematic situations and analyzing their correct responses as well as errors, and giving students manipulative materials and observing their reactions, the use of toys is recommended for diagnostic purposes. Toys lend themselves to such activities and many inexpensive toys are based on one or more scientific principles, particularly those from the physical sciences. These toys can be used either as motivation before a concept is taught or as evaluation. Take special notice of what the particular student perceives in the toy or what explanation the particular student gives.

Motivation. Piaget explains motivation in terms of his equilibrium theory. A state of disequilibration must exist in order for the child to be intellectually stimulated. Although each individual is seeking out stimulation, he/she is selective. Only the type of stimulation that can disequilibrate him/her becomes motivational. Piaget says that to catch the attention of a learner, the object, idea, situation, or event must be "moderately novel." The learner is not interested, and cannot be motivated, by what is too familiar; nor can he/she notice what is so new that it does not correspond to any of his/her schemes. Play and puzzles, according to Piaget, are excellent means of disequilibrating learners. This type of intrinsic motivation has much more merit for students with learning disabilities than do the prevalent extrinsic types of motivation currently used by teachers. Once learners have been intrinsically motivated, their attention spans also increase.

Science teachers must try to overcome the pervasive habit of providing explanations, mostly verbal, of a phenomenon without first arousing the curiosity of the students.

A Multisensory Hands-On Approach. Interaction with the physical environment is basic to Piaget's formulation on learning. Many science teachers who are given curriculums and materials to implement a multisensory hands-on approach have been disappointed when they could not induce the learning of science concepts. What has been overlooked is that the interaction with the environment should involve active intellectual reaction that can be stimulated by and acted out with the manipulative materials. In Piaget's words:

> Experience is always necessary for intellectual development... but I fear that we may fall into the illusion that being submitted to an experience (A demonstration) is sufficient for a subject to disengage the structure involved. But more than this is required. The subject must be active, must transform things, and find the structure of his own actions on the objects. (13)

As excellent as the new science curriculums with a hands-on approach may be, the science teacher must make the necessary modifications that take into account the cognitive levels and capabilities of all students.

Individualized Instruction. Social transmission of knowledge, which includes the child's interaction with adults as well as with peers, is one of the basic components of intellectual development and acquisition of knowledge. Piaget is critical of individualized programs when the learner is deprived of the intellectual challenge of questions, answers, and observations made by peers and adults regarding the concepts being learned. He expresses his criticism in the following statement:

> The sentimental and the natural worriers have been saddened by the fact that schoolmasters can be replaced by machines. In my view, on the other hand, these machines have performed at least one great service for us, which is to demonstrate beyond all possible doubt the mechanical character of the schoolmaster's function as it is conceived by traditional methods; if the ideal of that method is merely to elicit correct repetition of what has been correctly transmitted, then it goes without saying that a machine can fulfill those conditions correctly. (14, p. 77)

However, individualized activities can be useful in providing the kind of repetitive drill essential for reinforcing certain terms, definitions, processes, etc. They can help mostly in areas where memorization is needed. Instead of depending on individualized programs that isolate the learner, teachers can select and adapt some of the activities of such programs and prescribe them to learners as personalized experiences.

Global Exploration, Analysis, and Synthesis. Piaget's observations of the way a child explores objects has implications for all levels of instruction. "Perceptual or sensori-motor activity develops noticeably with age." During the early stages, the child remains almost passive when confronted with objects he/she has to identify. There is no decentration so that he/she does not really explore them at all. (16, p. 39) Later, the child learns to explore the object as a whole—what Piaget terms *global experience*. At a later stage, the child analyzes specific features. Finally, at the level of genuine operations, the child is able to explore the object systematically and with some kind of synthesis.

In order to study an area of knowledge in greater depth (and this is so true in science), it becomes necessary to isolate it from the main concepts it is related to. Considerable time is devoted to the study of leaves, the study of the sun, and so on in science classes. Most teachers are completely oblivious to the idea that these topics comprise only parts of a whole. Teachers assume that somewhere during previous experiences, learners have realized that a cell is a unit of structure in all living organisms, that a life function is only one of all the other life functions of an organism, that a leaf is a part of a whole plant, and that the sun is a part of a universe. We also assume that the learner is capable of integrating the newly acquired knowledge with what he/she may have been exposed to previously. However, most students are not able to perform this synthesizing task without assistance from the teacher.

This concept has particular implications for the instruction of students with special learning disabilities: many learners in this category are unable to perceive the relation of parts to whole. Instead, they perceive the topic being analyzed as an isolated fact. The science teacher can assist these learners by presenting the concept to be taught in its "global" aspect first and by constantly referring to the relation of the part being analyzed to the whole. When teaching about different parts of a plant, present a live plant and constantly refer to how and with what effect each function or structure is related to the whole plant. When teaching about change of physical state, use many more examples than just the change of state in water. Such sample strategies illustrate how science teachers can provide conceptual learning rather than fragmented, unrelated facts. This approach will also eliminate a number of misconceptions. When a high school biology student was exposed to the study of DNA, she expressed her confusion by saying, "How can there be atoms and molecules in a living cell? A cell is the smallest unit of a living organism, and atoms and molecules are the smallest particles of nonliving matter."

DEVELOPMENT OF LANGUAGE

Synoptic Exposé

Piaget argues that understanding concepts and dealing with abstractions require logical reasoning, not just familiarity with and ability to reproduce words and phrases that explain the concepts. Logical reasoning is primarily nonlinguistic. Piaget considers language—the ability to represent an object or an idea by a sign or symbol—as one of the semiotic functions. In addition to language, semiotic functions include imitation, play, and images. Understanding concepts and assimilating knowledge require internalized mental actions, *operations*, on the part of the learner. Piaget believes that logical structures and their prerequisite mental operations develop before language. "The acquisition of language presupposes the prior formation of sensori-motor intelligence." (15, p. 91) The vocabulary that a child progressively develops is meaningless babble unless these words are based on sensori-motor experiences that stimulate mental activity in the learner. Piaget is critical of scholars who reduce "the entire life of the mind to speech." (15, p. 83)

His explanation of the relationship of language to logic is as follows:

> Language does not constitute the source of logic but it is, on the contrary, structured by it. The roots of logic are to be sought in the general coordination of actions. (17, p. 90)

However, Piaget does not underestimate the role of language in the course of intellectual development. Language, as one of the semiotic functions, makes thought possible by providing an unlimited field of application. (17, p. 91) Elsewhere Piaget states:

> Language can constitute a necessary condition for the completion of logico-mathematical operations without being sufficient condition for their formation. (12, p. 68)

Piaget's observations have shown that language is deceptive with respect to thought and understanding.

Implications

Most science teachers rely on language as a medium for teaching, and they consider learners' verbal definitions of terminology or verbal explanations of concepts to be indications that the learners understand the underlying concept being taught.

Learning disabled children have problems with understanding and using language, whether spoken or written. Such learners may also have difficulty in expressing their understanding verbally or in written form. Contrary to the argument of many science teachers that students must know the definitions of terms before any teaching can take place, science can be taught with few verbal explanations. An effective strategy is first to provide appropriate activities that guide the learners to intuitively internalize the concept and then later to give the verbal explanation or term.

It is also important to remember that during the course of intellectual development, reasoning about things (concrete operation) develops prior to reasoning about verbal propositions (formal operation). Such realization may enable teachers to depend less on verbal explanations and more on concrete experiences.

It is also important for teachers to realize that language is deceptive with respect to thought and understanding. Teachers are often misled by the verbal facility of some students: they may believe that these students comprehend the concept and are able to handle more advanced concepts than they are actually able to. On the other hand, they are often fooled by the language handicaps of some students: they may think that such students have lower mental abilities than they actually possess.

DEVELOPMENTAL STAGES

Synoptic Exposé

Piaget describes intellectual development as evolving through various stages in the ontogenetic development of the child; it occurs in periods, stages, and substages in which each one lays the foundation for its successors. In Piaget's words, "Development is achieved by successive levels and stages." (11, p. 10)

Piaget recognizes four stages: the sensori-motor stage, the pre-operation stage, the concrete operation stage, and the formal operation stage. He continues to describe these stages:

> Let us note that these stages are precisely characterized by their set order of succession.... that is, in order to reach a certain stage... previous structures which make for further advance must be constructed. (11, p. 10)

This is one of Piaget's most popular formulations. What is often overlooked is that children do not pass through these stages at particular chronological ages; however, these stages do occur in a set order.

> They are not stages which can be given a constant chronological date. On the contrary, the ages can vary from one society to another. (11, p. 10)

He explains elsewhere:

> The maturation of the nervous system can do no more than determine the totality of possibilities at a given stage. A particular social environment remains indispensable for the realization of these possibilities. It follows that their realization can be accelerated or retarded as a function of cultural and educational conditions. (8, p. 337)

Researchers who have used Piaget's operational tests with different groups of children have found that all children do not reach the same developmental stage at the same chronological age. For example, there is a time lag of as much as four years between children in Martinique and children in France in reaching the same developmental stage. (14, p. 37)

We erroneously assume that students in secondary schools, because of their chronological age, have reached the formal operation stage. Any teacher can tell that a large number of his/her students do not exhibit the cognitive skills characteristic of this stage. Several studies confirm that many secondary school students, as well as some college students, have not acquired the cognitive skills appropriate to the stage of formal operation, although they have the potential to have attained this stage. (3,6)

Many seventh- and eighth-grade students assumed to be at the formal operational stage may still be in a period of transition from the concrete operational to the

formal operational stage.

Another of Piaget's observations that is often overlooked by teachers is that when a learner is confronted with an unfamiliar or difficult problem, he or she reverts to a previous stage of thinking.

Implications

Teachers at all levels of instruction must realize that not all of their students develop all their cognitive potential at the same rate. This is of particular importance to teachers who have been entrusted with teaching students with special learning problems. Many of the learning problems experienced by youngsters with learning difficulties are related to logical immaturity. Learners with perceptual or motor difficulties can be reached and often remediated with appropriate strategies. Learners who have had limited sensory experiences may manifest perceptual difficulties. Often learners are labeled as learning disabled when in actuality their "disability" is nothing more than a lag in maturation. Therefore, strategies that take into account the needs of these learners can help them reach the next stage of intellectual development as well as overcome their perceptual problems.

CONCLUDING REMARKS

We live in a scientific and technological world. Survival in such a world requires the development of a scientifically literate citizenry. We have often excluded the handicapped child from experiences in science, mainly because of archaic, elitist attitudes about the nature of intellect and about science.

Bronowski warns, in *The Ascent of Man*:

> A belief in the aristocracy of intellect... can only destroy the civilization that we know... we must be a democracy of the intellect.... (2)

Rostant calls for the democratization of science:

> Any distinction between the man of science and the ordinary man is no longer admissible, any more than a form of segregation based on an inequality of knowledge. Whether we like it or not... the time is clearly coming when the man in the street will have his say with regard to the great social, national, international and moral issues latently raised by certain applications of science.... (18)

We must not overlook the need to provide science education to all our learners including those with special learning problems. Various studies indicate that children with all forms of handicaps can learn science concepts and are interested and motivated by science activities. (1) Furthermore, direct experience with science phenomena given early in life and in large doses may help to reduce the deficits from which different types of handicapped learners suffer. (19)

Nevertheless, the task of teaching science to students with learning difficulties is not easy. Models of effective teaching strategies, appropriate instructional materials, and relevant curriculums for handicapped learners are scant. Piaget's conceptualization of the development of intellect and learning can assist teachers to plan, develop, and adapt strategies, materials, and curriculums in science that will involve those learners with special learning disabilities.

REFERENCES

1. Bennet, Lloyd M. "Science and Special Students." *Science and Children* 15(4): 12-14; December 1978.

2. Bronowski, Jacob. *The Ascent of Man*. Boston: Little, Brown and Co., 1973.

3. Buel, R., and Bradley, G. "Piagetian Studies in Science: Chemical Equilibrium Understanding From Study of Solubility." *Science Education* 56(1): 23-29; 1972.

4. Cruickshank, William. "Some Issues Facing the Field of Learning Disability." *Journal of Learning Disabilities* 5(7): 380-388; August/September 1972.

5. Danglade, Ruth, and Ball, Daniel. "Science for Someone Special." *Science and Children* 16(3): 23-24; November/December 1978.

6. Elkind, David. "Quantity of Conceptions in Junior and Senior High School Students." *Child Development* 32: 551-560; 1961.

7. Helmore, G.A. *Piaget: A Practical Consideration*. Elmsford, N.Y.: Pergamon Press, 1969.

8. Inhelder, B., and Piaget, J. *The Growth of Logical Thinking From Childhood to Adolescence*. New York: Basic Books, 1950.

9. Kirk, Samuel A. "Specific Learning Disabilities." *Journal of Clinical Child Psychology* 6(3): 23-26; 1977.

10. Lerner, J.W. *Children With Learning Disabilities*. Second edition. Boston: Houghton Mifflin, 1976.

11. Piaget, J. *The Child and Reality*. New York: Grossman Publishers, 1973.

12. _____. *The Origins of Intelligence in Children*. New York: International University Press, 1952.

13. _____. *The Psychology of Intelligence*. Littlefield, 1963.

14. _____. *Science of Education and the Psychology of the Child*. New York: The Viking Press, 1970.

15. _____. *Structuralism*. New York: Harper & Row Publishers, 1970.

16. _____, and Inhelder, B. *The Child's Conception of Space*. New York: Norton & Company, 1967.

17. _____. *The Psychology of the Child*. New York: Basic Books, 1969.

18. Rostant, Jean. "Popularization of Science." *Science* 131(3412): 1491; May 20, 1960.

19. Rowe, Mary Budd. "Help Is Denied to Those in Need." *Science and Children* 12(6): 23-25; March 1975.

20. U.S. Department of Health, Education, and Welfare. *1976 Annual Report of the National Advisory Committee on the Handicapped*. Washington, D.C.: U.S. Government Printing Office.

3. METRIC MEASUREMENT FOR BLIND STUDENTS

by Frank L. Franks

The author examines specific skills prerequisite to the development of measuring skills, and outlines an approach for developing these skills in the blind. Frank L. Franks is a research scientist in the Department of Educational Research, American Printing House for the Blind, Louisville, Kentucky.

The effects of lack of vision on learning and performance have received considerable attention in the literature on blindness. (1, 4, 8, 9, 12, 17, 21) However, the effects of lack of vision on mastery and comprehension of measurement concepts for blind students have received only limited attention. The review in the first section draws on existing literature to establish tentative guidelines for consideration in developing materials for blind students. The following section summarizes a program for introducing metric measurement to blind students developed at the American Printing House for the Blind, Louisville, Kentucky, with consideration of the guidelines; critical concepts and activities underlying the presentation of measurement are emphasized.

I. GUIDELINES FROM THE LITERATURE

It is generally accepted that all children progress through the same overall developmental sequence (7), although *the rate at which blind children reach various developmental levels may differ.* (11) It is essential that blind children be encouraged to gain information about themselves and their environment during the appropriate developmental phase in which this interest naturally occurs in all children. G.T. Scholl states that:

> Delays in the acquisition of skills beyond the stage of readiness may result in irreversible retardation or below-average performance of that skill. . . . There are . . . needs in physical and motor areas which must be satisfied if near-normal development is to be achieved. (18, p. 67)

F.E. Lord emphasizes that "environment must be made meaningful to [blind] children at an early age since attitudes toward travel and exploration are established during this period." (10)

In the absence of vision, the blind child must learn to develop her or his other senses in order to gain the needed understanding of self and environment. The tactual-kinesthetic sense has been recognized as an important avenue through which the blind child may acquire the necessary input. (5,11) Incorporated into the tactual-kinesthetic sense are the elements of touch, movement, and muscle memory. Motor movement, using the various body parts, enables the child to move out, explore, and interact with the immediate environment. (5, 20) For the blind child the possibility of variability, distortion, rigidity, and restriction is increased due to the loss of vision "as a unifying and structuring sense." (11) B.J. Cratty notes that a blind child's manipulative development may not be equal to that of a sighted child because of the apparent importance of visual stimuli for the investigation of manipulative behaviors by the child with normal vision. (3)

C.Y. Nolan, in a report on research in education of the blind, states:

> Visual deprivation results in a great reduction in the possible amounts of direct and vicarious contact with the environment. As a consequence, the proportion of experiences that must be classified as abstract is greatly increased for the blind. (14, p. 244)

M.H. Tillman observes that *the blind tend to approach abstract conceptualization problems from a concrete and functional level, and consequently lag behind sighted children.* (19)

The capacity to recognize, identify, discriminate, and manipulate the features and processes of the world around them is necessary for blind children if they are to acquire language. (2) I. Zwibelson and C.F. Barg suggest that blind children learn gradually to differentiate their environment through tactual and auditory modalities. They clarify the difficulty with word cognition that blind children seem to have:

> There is confusion between the spoken word and the meaning of the word as it relates to phenomenological experiences. One must consider that language is manufactured by sighted people and that the blind child's means of conceptualizing and perceiving reality are different than those of the sighted. It can therefore be expected that the methods used in learning language or the

sequences of language development of the blind and sighted children will be different. (22, p. 218)

In a study of three levels of concept development of blind and sighted children, aged 11 to 13, Zwibelson and Barg found that the blind subjects functioned primarily on a concrete and functional conceptual level and not on an abstract level. (22) The authors report that these results agreed with the observational studies of Nagara and Colonna (13) and Maxfield (16), and with the empirical study of Rubin. (17) S. Axelrod (1) and E. Omwake and A. Solnit (15) found that auditory and tactile tasks that were abstract in nature posed greater difficulty for early-blinded children than for sighted children.

Zwibelson and Barg feel that communication with blind children is possible because meanings, in terms of physical events that they have experienced, are similar, whereas referents require more refined discrimination. They suggest that blind children must be given ample opportunity to explore and manipulate their surroundings if verbal concepts are to develop. (22)

The considerations that follow are drawn from literature relating to problems imposed by lack of vision. They are stated as tentative guidelines for introducing metric measurement to young blind students. While several of the guidelines are very similar to those for sighted students, they are presented here because they are considered critical factors in the introduction of measurement to young blind students.

1. Totally blind students receive no sensory stimulation or input from visual aids and materials.
2. Legally blind students receive limited sensory stimulation and input from visual aids and materials, depending upon the amount of residual vision and visual efficiency of each student.
3. Instruction of blind students should emphasize tactual-kinesthetic experiences.
4. Motor activities involving exploration of the environment to acquaint the students with the components of their surroundings should be maximized.
5. Extensive activities in classifying, comparing, ordering, and measuring familiar objects close at hand should be encouraged.
6. Activities of a concrete and functional nature should be emphasized.
7. Abstract conceptualization in measurement should originate in and/or be related to concrete and functional activities.
8. Additional manipulative and explorative activities should be afforded blind students.
9. Prerequisite skill-related activities and games in measurement should be initiated at the kindergarten and preschool levels.
10. The young blind student should not be rushed from one phase of a program to another but should proceed systematically at her or his own rate.
11. Appropriate language and verbal concepts should be taught as they are used—not in isolation— and should be related to concrete objects in the environment.

II. THE APH METRIC MEASUREMENT PROGRAM

The program provides a framework or basic structure for developing the readiness component of a comprehensive metric measurement program for elementary-level blind students. It contains tasks and activities considered essential for preparing young blind students for measurement instruction as presented in the elementary mathematics curriculum. Teachers are encouraged to explain and illustrate vocabulary terms, to demonstrate measurement operations, to assist young blind students in performing and verbalizing these operations correctly, and to extend the program to include additional hands-on activities in the environment.

Basic measurement operations in linear measurement, volume, and mass are introduced. The scope of the program is the development of instructional materials that (1) provide prenumber measurement activities, (2) utilize basic number concepts taught by the teacher, and (3) combine the two to introduce number measurement. The sequence of activities emphasizes prenumber measurement experiences that provide background for the higher degree of abstraction required for measurement using numbers. The program was developed for students in grades K-6. Process-related activities in classifying, comparing, ordering, and measuring are integral components that are utilized in the instructional programs in linear measurement, volume, and mass.

Prenumber Measurement. Hands-on manipulative activities in classifying, comparing, ordering, and measuring without numbers are emphasized in prenumber activities to provide a base for introducing number measurement. Classifying activities include identifying objects and putting them together using height and length or volume or weight. Comparing activities establish relationships between the student and objects in the environment and between various objects using such comparisons as *taller* and *shorter* or *larger* and *smaller*. Ordering activities include the arrangement of objects and of sticks *from shortest to longest* or *from lightest to heaviest*. Measuring activities focus on tactual inspection and identification of component parts of measuring aids that later

will be used in performing measurement activities using numbers. Numerous manipulation experiences with objects over an extended period of time provide sensory experiences that can facilitate the acquisition of abstract mathematical concepts by young blind students. Consequently, additional measurement activities are suggested for younger students.

Number Concepts. The regular mathematics curriculum emphasizes the students' associating of number names with collections of objects, the naming of numbers, and the counting of collections of objects to identify the number. When students have acquired the concepts and language for some numbers, such activities as classifying, comparing, ordering, and measuring can include the use of these numbers. Naming the numbers 1 through 100 and counting to 30 are skills that will be necessary for minimal performance in the number measurement sections of the program.

Measurement with Numbers. Number measurement introduces standard units in metric measurement. Suggested number measurement activities are built on the experiences presented in the prenumber measurement section. With the introduction of standard metric units, students repeat the operational tasks, but this time they use numbers. For example, units on measuring sticks in prenumber measurement were used as nonstandard units. Students had no concept of *centimeter*. Now they learn that the centimeter is a standard unit by using it to perform a numerical measurement task (e.g., to measure a stick 7 centimeters in length).

Preparatory Activities for Young Blind Students. The measurement process for young children begins with their perception of objects that make up their environment. The opportunities for very young blind children to interact with their environment often are minimal and fragmented. Consequently, their perceptions of their surroundings, including the immediate environment, are severely restricted. Initial readiness activities in measurement for very young blind students should begin with exploring, manipulating, and classifying environmental components.

Although a number of classification activities are included in the program, such prerequisite or preparatory activities as identifying, labeling, and sorting objects at the kindergarten level are not provided in a specific introductory unit on classifying. When the readiness program is used with young students who have not learned these skills, appropriate activities that relate to natural experiences in the environment should be provided. It is not safe to assume that young blind students have learned these skills. They should have exposure to a wide range of experiences and objects in their environment and should discover properties of objects they will eventually measure. Some suggested preparatory measurement activities using accompanying program materials include:

1. Identifying objects (e.g., a spoon, a glass) when they are named: "Show me a spoon."
2. Identifying objects by name: "This is a glass."
3. Sorting objects: "Put the spoons in this box." "Put the small things in the tray."

For young blind students to achieve maximum comprehension of the measurement concepts introduced in this program, it is imperative that they have developed adequate body awareness, have identified concrete objects and their components (e.g., chairs, tables), and have mastered locational and directional referents critical to spatial orientation in their immediate environment. Observing and manipulating concrete objects in a known, familiar environment with the application of essential measurement vocabulary will foster the acquisition of a kinesthetic feeling for the metric units of measurement. This knowledge underlies the ultimate goal of accurate interpretation of the various symbols and relationships in metric measurement.

Body Awareness. Students need to perceive their own bodies and body parts accurately as the first step in developing a concept of body image. This is initiated through identification (e.g., nose, arm, foot) and classification (e.g., eyes, nose, ears, and mouth as parts of the head) of the following parts:

Head	Neck	Fingers
Eyes	Shoulders	Hips
Ears	Chest	Legs (upper, lower)
Nose	Stomach	
Mouth	Back	Knees
Teeth	Arms (forearms, upper arms)	Feet (ankles)
Tongue		Heels
Face	Hands (palms, backs of hands)	Toes
Hair		

Common Objects in the Environment. Students should be introduced to relevant objects and should systematically acquire knowledge of self and of these objects in relation to the environment prior to instruction.

1. Self is introduced in relation to an object (e.g., a chair): The student moves, the object does not.
2. An object in relation to self: The object is moved by the student.
3. Combined relationships: Focus is on self to object and object to self.

When identifying and classifying furniture (e.g., chair, table) used in the instructional units, the compo-

nent parts of each piece used (e.g., table—legs, top, edges) should be identified and classified during student exploration.

Spatial Orientation. A number of locational and directional referents successfully used by blind students as young as 5 were reported by F. Franks. (6) These referents have implications for facilitating movement in the environment, for organizing and manipulating objects for measurement activity tasks, and for introducing spatial concepts related to measurement. These referents are:

On, off	Middle, between
In front of, behind	Around, beside
Up, down	Along, across
Over, under	Near, far
Toward, away	Right, left

Activity Sequence. There are sequential activities involved in the three readiness sections of this program that are essential before young students can begin to acquire more abstract prenumber and number concepts. These activities are inherent in logico-mathematical operations that underlie the regular elementary mathematics program, as well as measurement.

The following sequence presents a representative breakdown for those teachers who wish to view the measurement program in terms of behavioral objectives, including preparatory activities for young blind students. Students will—

1. Name and identify common body parts on themselves and on others.
2. Place themselves in relation to objects.
3. Place objects in relation to the environment by using directional and locational referents.
4. Align objects' ends or place objects side by side in order to make direct comparisons.
5. Make simple comparisons/judgments of length and height, volume, weight, and area involving *less than* and *greater than*.
6. Understand that two objects and the qualities of two objects (length, height, volume, weight) are either the *same* or *different*.
7. Seriate (order) the qualities (length, height, weight, volume) of three or more objects.
8. Understand the quantitative terms *more* and *less* with respect to number.
9. Comprehend and execute the procedure outlined in the "mechanics" of measurement, using arbitrary units and measuring aids/worksheets.
10. Make simple estimations with respect to length, volume, and weight.
11. Use/develop a kinesthetic awareness of the standard units of measurement introduced in each area—linear, volume, and weight/mass.
12. Align objects with one-to-one correspondence.
13. Count by 1's to 30.
14. Count by 10's to 100.
15. Count/recognize numerals in print/braille to 30.
16. Seriate (order) any group of three or more given numerals between 1 and 100.
17. Understand ordinal terminology from *first* through *fourth*.
18. Measure objects to the nearest metric unit in each of the specific areas of the measurement program—linear, volume, and weight/mass.

Additional Learning Problems. Very young blind students and blind students who may be developmentally delayed or have motor or other problems require additional consideration. The teacher may wish to enrich a hands-on approach by assisting each student in placing and manipulating tangible materials. Complex activities involving several directions should be broken down into one-step tasks. Tasks should utilize a simplified vocabulary appropriate to the comprehension level of the students. Each task should be verbalized as the teacher goes through each movement. Variations in activities and in use of materials may be necessary, but these changes should not alter the measurement concept illustrated in the activity.

Representative Activities for Older Students. The APH program includes representative activities that focus on student performance for use with older students who have mastered many of the manipulation and performance activities written for younger blind students. The program is *not* designed to pinpoint readiness concepts within the unit for remediation with the use of specific activities. If a student cannot perform the representative activities successfully with ease, she or he should go through the entire unit.

III. EVALUATION

The program materials were developed at the Florida School for the Blind with some 50 students in grades K-6 participating. The materials were reviewed by mathematics content experts to ensure that they included critical measurement conceptual information contained in the elementary mathematics curriculum. After the materials were revised and edited, they were sent to centers across the country for evaluation by teachers who used them with blind students to determine their appropriateness. Since the materials development occurred in a residential setting, evaluation was concentrated in programs with

legally blind students mainstreamed in public school classes. More than 100 students from Massachusetts, Michigan, California, Tennessee, Colorado, and Washington, D.C., particpated.

Interviews and responses from teachers indicate that they were highly successful in using the materials. Students began with linear measurement and progressed through volume/capacity to mass/weight. Although there was not specific carryover from one unit to the next, students were reported to have acquired some transfer that facilitated learning as they progressed through the units. Some teachers reported using the materials with blind students in the regular class with the tactile aids serving as visual aids for the sighted students. In some instances the materials were used as the metric measurement program for the entire class. Kindergarten and primary grade teachers indicated that they were able to use the prenumber sections with very young students, and, consequently, *they were able to begin measurement instruction with the blind students at the same time that they introduced it to sighted students in the class.*

REFERENCES

1. Axelrod, S. "Effects of Early Blindness: Performance of Blind and Sighted Children on Tactile and Auditory Tasks." *American Foundation for the Blind, Research Series* 7; 1959.

2. Carroll, J.B. *Language and Thought.* Englewood Cliffs, N.J.: Prentice-Hall, 1964.

3. Cratty, B.J. *Movement and Spatial Awareness in Blind Children and Youth.* Springfield, Ill.: Charles C. Thomas, 1971.

4. Docecki, P. "Verbalism and the Blind: A Critical Review of the Concept and the Literature." *Exceptional Children* 32: 525-30; 1966.

5. Fraiberg, S. "Parallel and Divergent Patterns in Blind and Sighted Infants." *Psychoanalytic Study of the Child.* (Edited by R.S. Eissler and others.) Vol. 23. New York: International Universities Press, 1968. pp. 264-300.

6. Franks, F. *Introduction to Map Study: Teaching Locational and Directional Referents to Young Blind Students.* Doctoral dissertation. Nashville: George Peabody College for Teachers, 1974.

7. Gesell, A., and Ilg, F. *Child Development: An Introduction to the Study of Human Growth.* New York: Harper, 1949.

8. Juurmaa, J. *Ability Structure and Loss of Vision.* New York: American Foundation for the Blind, 1967.

9. Little, A. "Session Report: Research in Education of the Blind." *Blindness Research.* (Edite by M.H. Goldberg.) University Park: The Pennsylvania State University Press, 1969.

10. Lord, F.E. "Development of Scales for the Measurement of Orientation and Mobility of Young Blind Children." *Exceptional Children* 36: 77-81; 1969.

11. Lowenfeld, B., editor. *The Visually Handicapped Child in School.* New York: John Day, 1973.

12. Lowenfeld, B. *The Changing Status of the Blind from Separation to Integration.* Springfield, Ill.: Charles C. Thomas, 1975.

13. Nagara, H., and Colonna, A. "Aspects of the Contribution of Sight to Ego and Drive Development: A Comparison of the Development of Some Blind and Sighted Children." *The Psychoanalytic Study of the Child.* (Edited by R.S. Eissler and others.) Vol. 20. New York: International Universities Press, 1965. pp. 267-287.

14. Nolan, C.Y. "Research in Education of the Blind." *Blindness Research.* (Edited by M.H. Goldberg.) University Park: The Pennsylvania State University Press, 1969.

15. Omwake, E., and Solnit, A. "It Isn't Fair: The Treatment of a Blind Child." *The Psychoanalytic Study of the Child.* (Edited by R.S. Eissler and others.) Vol. 16. New York: International Universities Press, 1961. pp. 352-404.

16. Pinter, R.; Eisinson, J.; and Stanton, M. *The Psychology of the Physically Handicapped.* New York: Appleton-Century-Crofts, 1941.

17. Rubin, E.J. "Abstract Functioning in the Blind." *American Foundation for the Blind, Research Series* 11; 1964.

18. Scholl, G.T. "Understanding and Meeting Developmental Needs." *The Visually Handicapped Child in School.* (Edited by B. Lowenfeld.) New York: John Day Company, 1973.

19. Tillman, M.H. "The Performance of Blind and Sighted Children on the Wechsler Intelligence Scale for Children: Study I." *International Journal for the Education of the Blind* 16: 65-74; 1967.

20. Walker, D.L. *The Effects of Training on the Body Image of Blind Children of Kindergarten Age.* Doctoral dissertation. Nashville: George Peabody College for Teachers, 1971.

21. Worchel, P. "Space Perception and Orientation in the Blind." *Readings on the Exceptional Child.* (Edited by E.P. Trapp and P. Himelstein.) New York: Appleton-Century-Crofts, 1962.

22. Zwibelson, I., and Barg, C.F. "Concept Development of Blind Children." *New Outlook for the Blind* 61: 218-222; 1967.

4. MAINSTREAMING HANDICAPPED STUDENTS INTO SCIENCE CLASSROOMS

by Roger T. Johnson and David W. Johnson

The authors explore the meaning and purpose of mainstreaming and the value of cooperative groups as the goal structure within which this purpose can best be accomplished. Roger T. Johnson is Associate Professor of Curriculum and Instruction, and David W. Johnson is Professor of Educational Psychology, University of Minnesota.

As Wendy walked away from her resource room toward the science classroom, she was feeling uncomfortable. She turned to her special education teacher looking for support and found the teacher looking at her intently. She returned her teacher's quick smile and glanced through the classroom door at the busy hustle as students moved between classes. She didn't see the trace of anxiety appear on her teacher's face as she, too, peered into the classroom. Wendy slipped into an empty seat at the back of the classroom as the special education teacher and the classroom teacher chatted briefly.

Will I be liked? Will I be rejected? Will other students ignore me? These are questions that Wendy is asking herself. Such questions are at the heart of successful mainstreaming—the integration of students with intellectual, emotional, and physical handicaps into the regular classroom.

For the past several years we have been investigating procedures that regular classroom teachers can use to ensure that mainstreaming is a success. We began with three assumptions: (1) It is unfair and unrealistic to ask regular classroom teachers to become experts in special education; (2) Any teaching strategy implemented in the regular classroom to facilitate the integration of handicapped students should benefit the education of all students, not just those with special learning needs; and (3) Building positive relationships between handicapped and nonhandicapped students is the first priority of mainstreaming. When handicapped students are liked, accepted, and chosen as friends, mainstreaming becomes a positive influence on the lives of both handicapped and nonhandicapped students.

Why are handicapped students being integrated into the regular classroom? The purpose is to structure the classroom learning in such a way that—

1. Friendships are formed between handicapped and nonhandicapped students.
2. The social skills of all students are promoted.
3. The self-esteem of all students is enhanced.
4. The achievement of all students is maximized.

Sound great? Can it be accomplished just by placing handicapped students in the regular classroom and letting life proceed as always? *No, it can't.*

Placing handicapped students in the regular classroom provides the beginning of an opportunity. But, like all opportunities, it carries the risk of making things worse as well as the possibility of making things better. If things go badly, handicapped students will be stigmatized, stereotyped, and rejected. Even worse, they may be ignored or treated with the paternalistic care one reserves for pets. If things go well, however, true friendships and positive relationships may develop between the nonhandicapped and the handicapped students.

What does the regular classroom teacher do to ensure that mainstreaming goes well? The answer goes beyond explanations of the law, additional forms to complete, extra meetings to attend, or lectures on various learning, emotional, and physical disabilities. What is needed is an understanding of how the process of acceptance works in a classroom setting and of how specified teaching strategies help to build positive relationships between handicapped and nonhandicapped students as they attend the regular classroom together. This article defines mainstreaming, recognizing the relationship between handicapped and nonhandicapped students as a key issue; describes the specific strategies for setting up heterogeneous cooperative groups of handicapped and nonhandicapped students to encourage acceptance, friendships, and higher achievement; and points out the strong relationships between learning in cooperative groups and the area of science.

INTEGRATION INTO THE MAINSTREAM

First, let us look at a definition of mainstreaming. Any definition of mainstreaming is incomplete if it does not include the premise that it should be conducted to

maximize the likelihood of handicapped students' access to constructive interactions with nonhandicapped peers and to normal life experiences. Placing a handicapped student in the corner of a classroom and providing individualistic learning experiences is not effective mainstreaming. Mainstreaming is successful only if it fosters friendships between handicapped students and nonhandicapped peers. (3, 5) Thus, a complete definition of mainstreaming is as follows:

Mainstreaming is the provision of an appropriate educational opportunity for all handicapped students in the least restrictive alternative, based on Individualized Education Programs, with procedural safeguards and parent involvement, and *aimed at providing handicapped students with access to* and *constructive interaction with nonhandicapped peers.*

What does the mainstreamed classroom look like? Exceptional students usually spend more than half the day in regular classrooms, leaving occasionally to go to a resource room or resource center either to participate in educational assessments, individual tutoring, or small-group instruction, or to pick up and deliver assignments prepared by the resource teacher but completed in the regular classroom. The resource teachers and the regular classroom teacher, working as a team, may schedule a student to use the resource center for a few minutes or several hours, depending on the student's learning needs. The regular classroom teacher and the resource teacher share responsibility for the learning and the socialization of exceptional students, and both take an active instructional role. The regular classroom teacher, who is responsible for grades and report cards, usually consults with the resource teacher in grading exceptional students.

One other point needs to be made about students' access to each other in the classroom: It is effective and proper for classroom teachers to hold a broad definition of mainstreaming when it comes to interactions within the classroom. The "very quiet" student sitting by the window, the "very bright" child sitting near the front, the "disruptive" student at the back, and the responsible, "average" student seated in the middle of the room all need to be mainstreamed in the class setting right along with handicapped students. All students gain by being part of a classroom climate emphasizing the building of accepting, helping, and sharing behaviors.

Learning outcomes for all students are discussed briefly in a later section of this article. For the moment, let us turn to one of the initial problems in mainstreaming—the attitudes of nonhandicapped students toward their handicapped peers.

Desirable Kinds of Interaction

Whether interaction between handicapped and nonhandicapped students results in a process of acceptance or rejection is determined by the type of interdependence among students' learning goals and rewards, which is structured by the teacher. Within any learning situation, a teacher can structure positive goal interdependence (i.e., cooperation), negative goal interdependence (i.e., competition), or no goal interdependence (i.e., individualistic efforts). (4) In a *cooperative* learning situation, students' goal attainment is positively correlated, and students coordinate their actions to achieve the goal. Students can achieve their learning goal only if the other students with whom they are cooperatively linked achieve their learning goal. In a *competitive* learning situation, students' goal attainment is negatively correlated, and one student can obtain his/her goal only if the other students with whom he/she is competitively linked fail to obtain their learning goal. In an *individualistic* learning situation, the goal achievement of each student is unrelated to the goal attainment of others; there is no correlation among students' goal attainment. Students' successes are contingent on their own performance irrespective of the quality of performance of others.

When mainstreaming begins and handicapped students first enter the regular classroom, nonhandicapped students form an impression of their handicapped classmates, categorize the observable characteristics, and attach labels to the categories. The labels of *mentally retarded, learning disabled, emotionally disturbed, hearing impaired,* and so forth have negative connotations that carry stigmas. From the beginning, therefore, handicapped students are perceived somewhat negatively, and this perception sets up the strong possibility of a process of rejection by nonhandicapped peers.

Student-Student Interaction

Each goal structure promotes a different pattern of interaction among students. Aspects of student-student interaction important for learning are accurate communication and exchange of information, facilitation of each other's efforts to achieve, constructive conflict management, peer pressures toward achievement, decreased fear of failure, divergent thinking, peer acceptance and support, use of each other's resources, trust, and emotional involvement in and commitment to learning. (4) Cooperation provides opportunities for positive interaction among students, while competition promotes cautious and defensive student-student interaction (except under very limited conditions). When students are operating within an individualistic goal structure, they work by themselves to master the skill or knowledge assigned, without interacting with other students.

Thus, the cooperative goal structure is consistent with the intent of mainstreaming—that handicapped students have access to and constructive interaction with their nonhandicapped peers. This doesn't mean that competition and individualism are done away with com-

pletely. In the ideal classroom all three goal structures are used appropriately. All students learn how to compete for fun and enjoyment (win or lose), to work on their own and follow through on an individualistic task, and to work cooperatively with other students. However, the major student-student interaction pattern should be cooperation, not only because it has been demonstrated to be the most effective for all the students, but also because positive mainstreaming is facilitated by the cooperative interaction pattern and hindered by competition or individualism. Let us look at the process of acceptance briefly for further clarification of this conclusion.

THE PROCESS OF ACCEPTANCE

The process of acceptance begins with handicapped and nonhandicapped students' being placed in small, heterogeneous learning groups and being given the assignment of completing a lesson as a group, making sure that all members master the assigned work. In other words, a positive interdependence is structured among students' learning goals. There is a great deal of research comparing the effects of cooperative, competitive, and individualistic learning. (4, 5) Compared with competitive and individualistic learning situations, working cooperatively with peers—

1. Creates a pattern of promotive interaction, in which there is—
   a. more direct, face-to-face interaction among students.
   b. an expectation that one's peers will facilitate one's own learning.
   c. more peer pressure toward achievement and appropriate classroom behavior.
   d. more reciprocal communication and fewer difficulties in communicating with each other.
   e. more actual helping, tutoring, assisting, and general facilitation of each other's learnings.
   f. more openmindedness regarding peers and more willingness to be influenced by their ideas and information.
   g. more positive feedback to and reinforcement of each other.
   h. less hostility, both verbal and physical, expressed toward peers.
2. Creates perceptions and feelings of—
   a. higher trust in other students.
   b. more mutual concern and friendliness for other students, more attentiveness to peers, more obligation to and responsibility for classmates, and a greater desire to win the respect of other students.
   c. stronger beliefs that one is liked, supported, and accepted by other students, and that other students care about how much one learns and want to help one another learn.
   d. lower fear of failure and higher psychological safety.
   e. higher valuing of classmates.
   f. greater feelings of success.

As nonhandicapped students work closely with handicapped peers, the boundaries of the handicap become more and more clear. While handicapped students may be able to hide the extent of their disability when they are isolated, the intensive promotive interaction under positive goal interdependence promotes a realistic as well as differentiated view of the handicapped students and their disabilities. If a handicapped member of a learning group cannot read or speak clearly, the other members of the learning group become highly aware of that fact. With this realistic perception, however, there also come a decrease in the primary potency of the handicap and a decrease in the stigmatization connected with the handicapped person.

One other outcome of cooperative grouping is important to any discussion of acceptance of differences. A direct consequence of cooperative experiences is a positive cathexis (1, 2, 4, 5) in which:

1. The positive value attached to another person's efforts to help one achieve one's own goals becomes generalized to the other person, and
2. Students positively cathect to their own actions aimed at achieving the joint goal and generalize that value to themselves as persons.

In other words, when interaction occurs within a context of positive goal interdependence, the acceptance of and liking for handicapped peers by nonhandicapped students increase, and the self-attitudes of handicapped students become more positive.

STRUCTURING LEARNING COOPERATIVELY IN SCIENCE CLASSROOMS

In many ways, the science classroom is an excellent setting for mainstreaming. Science classes often focus on apparatus and experimentation rather than being bound by reading and writing skills as requirements for success. Having students work together is not new to science teachers; they often group students, even when they are not sure they want to, due to a short supply of materials or equipment. Even when materials are plentiful, a teacher may put four or five students together so that they can help each other discover how to light a bulb or complete a

lab assignment. The expectation of the current, inquiry-oriented programs in science is that students will interact with each other, sharing information, generating alternative ideas, inventing tests to try out each other's ideas, and sharpening inferences through discussion. However, until recently, little information has been available about the specific strategies for structuring cooperation among group members so that groups, and especially heterogeneous groups, can work effectively and build positive relationships.

What are the steps to be used in structuring cooperative learning in science classes? The following guidelines do not constitute a formula, but rather a model that many science teachers have found helpful. This brief summary of the specific strategies designed to assist the teacher in setting up cooperative groups is taken from *Learning Together and Alone*. (4) To make the model more concrete, the example of its use with the *Mystery Powders* unit from the Elementary Science Study (McGraw-Hill, 1968) will be included.

Assignment

The first step for a science teacher in structuring a cooperative learning activity is to select an appropriate group size and assign students to groups. For the *Mystery Powders* unit a science teacher might divide a class into groups of four students each—enough group members to stimulate each other's thinking but not enough to allow one or more students not to participate. With 32 students in the class, groups are formed by having students randomly count off by eights. The "ones" become a group, the "twos" another, and so on. The teacher's intent is to form heterogeneous groups in which students have different backgrounds, perspectives, and skills. Heterogeneous groups are potentially the most powerful in problem-solving situations. Sometimes students will ask if they have to work with the group they have been assigned to; they can be told that eventually they will work with everyone in the class and that this is their group for today.

Room Arrangement

The second step is to arrange the room and the science materials to promote collaborative interaction among students. Group members should sit close together, separated as far as possible from the other groups. The mystery powders and apparatus are set out on a centrally located table. One person from each group gets the materials for the group.

Cooperative Learning Goals

The third step is to assign the task and describe the cooperative structure of the learning goals. To assign the task, the science teacher asks students to use their prior experiences with referent powders to analyze a "mystery powder" which might be one of the referent powders, a combination of the referent powders, or a new powder. To set the cooperative structure of the learning goals, the teacher asks each group to submit at the end of the class period *one* report describing the students' best opinion as to what the powder is and the group's rationale for its decision. Group members are told to sign the report only if they agree with the answer and can explain the rationale. The students are told that they should share ideas, listen to each other's ideas, participate in the testing process, ask other group members to verify the results, and double-check test results and information with other groups when it seems necessary. The evaluation criteria are as follows: if the group report is 100 percent correct, the group has done an excellent job; if the report is partially correct, the group has done an acceptable, but not an outstanding, job; and if the report is way off, the group is sent back to the drawing board (or the powder, in this case).

Formal and Informal Observation

The fourth step is to observe the groups of students. Assigning students to groups and asking them to work cooperatively does not mean they will or can do so. Teachers can use a formal observation sheet to check specific aspects of cooperative interaction, such as participating actively in testing powders, listening actively to other students' comments, presenting logic rather than forceful opinion to the group, and summarizing data and the group's conclusions. After the teacher has observed and modeled how to share observations without making judgments about students' actions, students may be given the opportunity to use the formal observation sheet. Observing a group is probably the best way for students to learn cooperative skills—students concentrate on the presence and absence of the skills and see them used or misused as the group learns science.

As the teacher moves around the room, he/she may also make informal notes. A disagreement arises in one group over which powder is the whitest. One student who had been quiet takes out a piece of white construction paper and places a sample of each powder on the paper. The other group members see which powder is whitest, and they move on with their analysis. When observing such student-student interaction, the teacher can jot down a few notes to expand on later when reflecting over the observational and achievement data and making conclusions about the class's progress in learning science and cooperative skills.

Intervention To Teach Social Skills

The fifth step in conducting a cooperative science lesson is to intervene to teach collaborative skills in

groups that have difficulties working together. A group, for example, may be leaving out one member. The teacher may stop the group, pointing out that not everyone is being included and, therefore, that the group is losing resources and will have difficulty getting everyone to sign the report at the end of the class period. In response to the teacher's observation, the group may decide to check every few minutes to make sure that everyone is participating and understands what the group is doing. The group then proceeds with its analysis of the mystery powder. The teacher may watch for a moment or two and then move on to observe another group.

The basic cooperative skills students need to master are trust building, communication, leadership, and conflict resolution. (4) Collaborative skills must be defined so that students will understand how to behave cooperatively. Some groups may have problems integrating the cooperative skills into their efforts to complete the assigned task. The teacher must be able to say, "Put away the powders for a few minutes. We've got a cooperative skills problem to solve." The teacher then stays with the group as the group solves its problem.

Evaluation of Students' Work

The sixth step is to evaluate the quality and quantity of the students' learning. The teacher collects the groups' reports and evaluates them according to the preset criteria. Students may evaluate the functioning of their groups by spending the last ten minutes of the period discussing how well they worked together and each member's contributions to analyzing the powder. The teacher may offer some overall observations and listen as the groups share their summaries with the class.

To examine how this model operates to enhance mainstreaming, let us return to the story of Wendy:

Wendy looked around the classroom, hoping that the other students would not notice her. She was able to manage a small smile as the special education teacher gave her an encouraging nod and left the room. The teacher signaled for quiet and asked the students to "count off" to form today's science groups. Joining her learning group, Wendy shyly studied the faces of Sally, Jack, and Sam as they jovially assembled. After Jack had brought back materials for the group, Sally suggested that the group start with the "vinegar" test on the mystery powder to see if it reacted with acid. Wendy began to feel panic as the group discussed what they were going to do to analyze the powder and began edging her chair back from the table. When Sally, Jack, and Sam turned to her for her opinion, she backed her chair farther away and looked away from their expectant faces as tears began to overflow, despite her best efforts to hold them in.

The teacher quietly appeared at Wendy's side and asked what was wrong. "I don't want to work with anybody," she gasped. "I want to go back to my special classroom!"

Observing Wendy's fright, the teacher suggested, "The group needs someone to record its answers. Why don't you be the recorder for the group? Sally, Jack, and Sam would appreciate the help because they are going to need careful notes to complete the assignment."

After Wendy was moved back into the group with paper and pencil, the teacher moved to where she could watch the group work. Wendy was clearly taking the responsibility of recorder seriously; as the others shared the information with her, she listened carefully to the inferences and wrote them down as neatly as she could. Sally especially seemed skilled in explaining the inferences to the group and in assisting Wendy in writing them down.

The next day, observing Wendy's enthusiastic participation in the group, the teacher smiled across the room to the smiling special education teacher standing in the doorway.

The story of Wendy is based on an actual occurrence in a school where the authors were consulting. The experience illustrates several important aspects of using heterogeneous cooperative groups for instructional purposes. It is important that any science teacher who is mainstreaming special education students develop a "teaming" relationship with the special education teacher who can provide support for what is occurring in the classroom, assist in teaching the group skills necessary for handicapped students to be successful in cooperative groups, help to set reasonable expectations as to handicapped students' work, and provide classroom assistance in setting up cooperative groups. After cooperative groups are organized, students need to be reminded that it is a "sink or swim together" situation—that every student is a member of the group and needs to feel a part of the group and to know the material. This may require some assignment of specific roles and social skill teaching. Perhaps most of all, we need to keep in mind that the purpose of mainstreaming is not merely a matter of learning the material; it is really a matter of social acceptance and friendship among students who have been taken out of the regular classroom and labeled handicapped and those who have remained in the classroom without that label.

Although many good science teachers have moved away from the predominantly competitive mode of present classrooms to the use of cooperative groups, for many other teachers the use of cooperative groups, as described here, will seem to be a departure from present practice. Therefore, a brief "back to basics" statement seems advisable. The use of heterogeneous cooperative learning groups benefits not only the handicapped students being mainstreamed, but also the average and gifted students in the regular classroom. (4) The teaching procedures are straightforward enough so that any teacher can learn them. Yet the importance of cooperative learning experiences goes beyond the integration of handicapped students into the regular classroom and the resulting increases in friendships, social skills, self-esteem, and achievement. Cooperation is as basic to humans as the air we breathe. The ability of all students to work coopera-

tively with other people is the keystone to building and maintaining stable families, careers, and friendships. Being able to perform technical skills such as reading and math are of little use if a person cannot apply them in cooperative interaction with other people in career, family, and community settings. The most logical way to emphasize the use of student's knowledge and skills within a cooperative framework, such as they will meet as members of society, is to use cooperative learning groups in the classroom. A very good case can be made to support the contention that nothing is more basic in education than learning to work cooperatively with other people.

Positive Values

Like many strategies in "sciencing," cooperation among students should not be limited to inquiry situations or to science classes. Data on students working together on a set of math problems, or a set of comprehension questions for a story, or other subject areas, are just as positive. The use of cooperative groups with appropriate social skill teaching is a powerful instructional technique. Learning situations where complex or critical thinking is desired become a place where the positive interaction among students improves their possibilities for success. Science, with its emphasis on experimenting and critical thinking, is an excellent place to start cooperative learning and to teach the social skills students need to work effectively with each other.

SUMMARY

The central question for the classroom teacher who will become involved in mainstreaming is, "How will handicapped and nonhandicapped students interact with each other?" Placing handicapped students in the regular classroom is the beginning of an opportunity, but, like all opportunities, it carries the risk of making things worse as well as the possibility of making things better. Physical proximity of handicapped and nonhandicapped students does not guarantee positive attitudes and increased acceptance; increased prejudice and rejection may be the result. The crucial factor is determining whether a process of acceptance or a process of rejection occurs in the classroom is the kind of student-student interaction fostered by the teacher. While competitive and individualistic behaviors tend to support rejection, cooperative interactions between handicapped and nonhandicapped students encourage the positive social interactions that bring handicapped students into the mainstream of classroom society. It is crucial to note that structuring learning cooperatively is not something done solely for the handicapped students; it is beneficial to all students. The research indicates that cooperation encourages higher achievement and more appropriate self-esteem for all students and more positive social interactions throughout the classroom. Equally important is the fact that cooperative instruction is based on a set of practical strategies that any teacher can master. It does not require the classroom teacher to become an "expert" in special education.

REFERENCES

1. Deutsch, M. "A Theory of Cooperation and Competition." *Human Relations* 2: 129-152; 1949.

2. _____. "Cooperation and Trust: Some Theoretical Notes." *Nebraska Symposium on Motivation.* (Edited by M.R. Jones.) Lincoln: University of Nebraska Press, 1962. pp. 275-320.

3. Johnson, David W. *Educational Psychology*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1975.

4. Johnson, David W., and Johnson, Roger T. *Learning Together and Alone: Cooperation, Competition and Individualization.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1975.

5. _____. "Many Teachers Wonder... Will the Special Needs Child Ever Really Belong?" *Instructor* 87: 152-154; February 1978.

5. COOPERATIVE GOAL STRUCTURES AND THE MAINSTREAMING OF HANDICAPPED STUDENTS

by Marshall Corrick

An examination of the practical techniques for the effective use of cooperative groups in a heterogeneous mainstream science class. Marshall Corrick is a science instructor, Lincoln High School, Bloomington, Minnesota.

INTRODUCTION

Cooperative groups, when effectively used, have been shown to be one of the most powerful tools available to educators. An excellent case for the use of heterogeneous cooperative groups has been made by David W. Johnson and Roger T. Johnson in their book *Learning Together and Alone*. (1) I will not try to replicate that discussion here. However, the cooperative goal structure should not be considered either the only or the final cure for every educational frustration. It is a tool—one of the most versatile and practical tools available—and, when skillfully used by a perceptive and creative teacher, it can provide the channel for the integration of handicapped students into the mainstream classroom in a manner that is successful, satisfying, and productive.

As a point of reference, it might be well to offer a definition of *handicapped*. When I speak of a *handicapping condition*, I speak of any condition or characteristic that prevents the appropriate learning, or the manifestation of that learning, from occurring. This condition may result from the interaction of the classroom environment with one or more of the following disabilities: (1) physical; (2) mental; (3) perceptual; (4) emotional; (5) educational; (6) motivational; (7) social; and (8) situational. This definition is broader than the legal definition used for the allocation of funds, but it is a practical definition with significant implications for the science class. Among these are the following: (1) Every student has both abilities and disabilities; (2) Disabilities become handicaps only when they prevent appropriate functioning in a given setting; (3) The optimal learning environment is one that allows maximum utilization of abilities while minimizing the handicapping effect of disabilities; (4) The use of cooperative goal structures is a viable strategy for the promotion of this learning environment.

The effectiveness of cooperative groups is, however, dependent upon the common goals and group skills of the membership. Developing "group" goals and improving the skills of the individual group members in the performance of task and maintenance functions will enhance both the quality of the group product and the quality of the group experience itself. This article will attempt to detail an approach to the development of effective cooperative groups in the junior high school science class.

FORMING HETEROGENEOUS, BALANCED GROUPS

Effective group formation is more than the random alignment of bodies. Thought must go into the assignment of group members so that each individual has a reasonable potential for making a positive and valued contribution to the group, so that the various skills of the group members supplement or enhance one another, and so that the groups are balanced such that each group has a similar potential to accomplish the class goals. In forming these balanced groups, consideration should be given to the development of heterogeneity in the areas of sex, race, color, and ethnic background; functional level; perceptual ability; motivation; academic background and ability; interests; and skills.

One way to begin forming balanced, heterogeneous groups is with the basic skills method. In this approach, tasks to be completed in accomplishing the group goals are broken down into their basic skill components. The students are then assigned according to their skill in a basic component area. This assignment is made on the basis of the student's self-perception and pretest data. An example is given below. In this example, one of the tasks in goal accomplishment is keeping a group notebook. A component skill is the ability to write neatly and legibly. This component is translated into the group role of *scribe*. Similar reasoning resulted in the other four roles.

Sample Base Group

The base group will consist of five members, each having one of the following skills:

1. *Scribe.* The scribe will be able to record the results of the group activities in a neat and properly organized form.
2. *Artist.* The artist will be able to make a recognizable artistic reproduction of the laboratory setups used in each experiment.
3. *Scholar.* The scholar will be able to read short passages and sets of experiment directions, and explain or summarize them for the group.
4. *Mathematician.* The mathematician will be able to make the basic mathematical computations necessary to complete and interpret experimental results.
5. *Socializer.* The socializer will work toward the union of all members of the group into an effective, cooperative whole.

A second example for a more homogeneous high school elective class in science is given below.

Sample Base Group

The base group will consist of four members, each having one of the following skills/responsibilities:

1. *Researcher.* The researcher is responsible for researching the topic, defining the problem, and suggesting hypotheses.
2. *Technician.* The technician is responsible for investigating the problem, designing experiments, listing materials, and suggesting variables.
3. *Analyzer.* The analyzer is responsible for interpreting the data, preparing graphs and charts, suggesting relationships, and expressing the conclusion.
4. *Recorder.* The recorder is responsible for reporting the data and recording the experimental procedures and the results in an understandable and concise form.

To ensure further balance, additional techniques such as the following may be used:

1. *Subject proficiency.* In this technique, students' grades or other criteria are used to develop heterogeneity. Each group is comprised of a mixture of students of varying degrees of ability in the subject matter, providing for an academically balanced group.
2. *Leadership skills.* The effectiveness of a cooperative group depends in part on the level of skill among its members in performing task and maintenance functions. A detailed discussion of this is given in *Joining Together.* (2) Attention should be given to the dissemination of leadership among the groups and to the development of leadership within the group.

Although much emphasis has been given to the process of group formation, the reader should not be overwhelmed by the magnitude of the task. This is a goal rather than a prerequisite. Cooperative groups have a tremendous ability to adjust and compensate. And many of the skills can be developed within the group. If groups are motivated and facilitated, they will not allow their disabilities to become their handicaps.

DEVELOPING COMMON GOALS AND GROUP MOTIVATION

Students will make no commitment toward improving their own group functions to facilitate the accomplishment of group goals unless there is a commitment to the group itself. The group goals must become the individual goals. This is developing the "we" feeling. In order to develop this feeling, it is very important that the first interdependent activity be nonthreatening and positive. The following are some that work well:

1. *Group crest.* Developing a group crest includes (1) choosing a name (consensus)—this may be limited to the content the group will be studying (e.g., it must include the name of a mineral); (2) determining and drawing an appropriate group symbol (group creativity); (3) identifying the group members and their functions (group identity); (4) choosing an appropriate symbol for each member (individuality); and (5) displaying the finished product for the class ("We are the ....").
2. *Group introduction tape.* This strategy is similar to the group crest. Each group is given a tape recorder and tape. They are to introduce themselves by giving (1) the group name ("We are the...."); (2) the significance of their name (group creativity); (3) the names of each group member (individuality); (4) the function of each group member (responsibility); and (5) one or two positive things about that person that make her or him appropriate to that role (trust building).
3. *Group presentation.* In this strategy, each group is asked to make a short presentation to the rest of the class on a current topic of interest germane to the subject area. They are told to be as creative as they wish, presenting a report, panel discussion, skit, TV talk show, radio broadcast, pantomime, audio or visual aids, etc. They are to be evaluated on *content* (cooperative group effort), *presenta-*

tion (group creativity), and *participation* ("We are....").

4. *Low-level competition.* [To avoid the negative aspects of competition while maximizing the positive, see Johnson and Johnson's *Learning Together and Alone.* (1)] In this strategy, cooperation within the groups facilitates the competition against other groups and strengthens the group identity. An appropriate first prize for this might be a team photo holding a big #1 (the "we" feeling).
5. *Comparative problem solving.* In this strategy, the groups are placed in a problem-solving situation with one-third operating competitively, one-third operating individually, and one-third operating in heterogeneous cooperative groups. The results are then examined, comparing the rate of problem solving, the quality of the product, and the quality of the problem-solving experience itself. This is repeated with new problems until each group has experienced all three goal structures. As a follow-up, an individual test is given over all of the problems and the student results are compared to the type of goal structure used in each of the problem-solving situations. This strategy is useful in establishing the value of cooperative groups not only for the student, but also for the hesitant teacher.

DEVELOPING GROUP SKILLS

As stated earlier, the effectiveness of cooperative groups is dependent not only on the skill with which the groups are formed and the establishment of common goals among the membership, but also on the presence and practice of group skills in and by the participants. Johnson and Johnson give a detailed discussion of these skills. (2) What follows is based on this discussion with a few alterations.

The skills important to the function of cooperative groups can be divided into five general areas:

1. *Task completion skills* involving giving direction, initiating action, stimulating, coordinating, and summarizing.
2. *Communication skills* involving giving and seeking information, clarifying, facilitating, and receiving both opinions and feelings.
3. *Group maintenance skills* involving encouraging participation, relieving tension, sharing feelings, building trust, resolving conflicts, and increasing togetherness.
4. *Controversy skills* involving expressing problems in terms of ideas rather than personalities, harmonizing, compromising, differentiating, integrating, perspective taking, and evaluating.
5. *Observation skills* involving diagnosing sources of difficulties, observing group processes, facilitating feedback, and analyzing functions being performed or needing to be performed by group members.

Once it has been determined what skills need improvement, several strategies can be used. Among these are the following:

1. *Specific skill activities.* Two examples of this are the "encouraging participation exercise" and the "distributed information exercise." (2)
2. *Role playing.* This can either be impromptu, with the students drawing cards with the assigned roles, or be planned, with the students choosing one or more group functions that they consciously role play over a period of time until these functions become a natural part of their group behavior.
3. *Process observers.* One of the most important techniques for the improvement of cooperative group skills is the careful use of process observers to provide feedback to the group members concerning the functions begin modeled by their behaviors.
4. *Teacher intervention.* Probably the most effective approach to skill improvement, however, is teacher diagnosis and intervention. In this technique the teacher makes observations of groups in action, diagnoses difficulty resulting from the lack of a certain skill, and intervenes to teach that skill to the group having problems.

DEALING WITH THE DISABLED IN COOPERATIVE GROUPS

One advantage of heterogeneous cooperative groups is that the focus can be placed on the abilities of a student rather than her or his disabilities. To prevent disabilities from becoming handicaps, however, they must be diagnosed and dealt with. Some general approaches can be used which help to establish a classroom atmosphere that is open and accepting:

1. *Avoid stereotyping.* Terms such as *jock, freak, dumb, brain, retard, wierdo, klutz, lazy,* etc., should be banned from the classroom. Each student must be accepted as a person, a unique individual of significance and worth. At an age when

students are struggling to define who they are, where they belong, and what they are worth, it is extremely important that the classroom become a place where each is an individual, everyone belongs, and all have a worthwhile contribution to make.

2. When a group is having a problem functioning, *separate problems from personalities*. Never accept "he" or "she" as the source of, or the solution to, a problem. Emphasize the group. The assigned task is a group problem that must be solved by the group. Stress the functions that need to be peformed by the group in order to solve the problem.
3. *Value the process as well as the products*. Reward cooperative behavior. Encourage participation. Evaluate maintenance functions. It is not only what the group does that is important but also what it is.
4. *Assign achievable responsibilities to each group member*. Rotate some of these responsibilities to change the roles of individuals in the group. Suggested roles include:
   a. *Curator*. The curator will take charge of all group materials to see that they are properly cared for and available when needed.
   b. *Custodian*. The custodian will be in charge of the checkout and return of all laboratory supplies and will be accountable for their safe and proper use.
   c. *Organizer*. The organizer will determine the group tasks, make individual assignments, and set goals for each activity period.
   d. *Moderator*. The moderator will be responsible for settling disputes, maintaining the task orientation, and acting as the communicator between the group and the instructor.
   e. *Reporter*. The reporter will make observations of the group at work and report to the instructor on both the group process and the product.

Achieving an education has been compared to negotiating an obstacle course. There are many barriers of which only part are natural. In dealing with specific disabilities, the concerns are these: What are the barriers? Which of these can be negotiated? Which can be circumvented? Which can and should be removed?

The barriers to the physically disabled are the most obvious, and an attempt has been made over the past several years to make schools barrier free. There is much to be done, however, if the classroom is to be barrier free for such disabled students as the hearing impaired and blind. The cooperative group can do much to overcome the barriers, psychological as well as physical, that still exist. Often students who are physically disabled may be talented or even gifted in other areas. Given opportunity and encouragement, students have been shown to relate very well to the physically disabled child.

The barriers encountered by students with mental, educational, or perceptual disabilities are very similar, usually including reading difficulty, a poor self-concept, and an inability to compete in areas requiring written interpretation and expression. It is important that both the students and the teacher recognize that this is not the only mode of learning and expression. Some students who read and write poorly are very articulate in oral communication. Some who cannot conceptualize a solution can visualize creative and innovative approaches to the solution. Cooperative groups can offer students the opportunity for this flexibility and creativity.

Two groups that are often the most difficult for teachers to deal with are those students with handicapping conditions resulting from emotional and motivational disabilities. These are the "turned off" students, the nonparticipants, the behavior problems. It is for these groups that cooperative goal structuring has shown some of its greatest potential. The heterogeneous cooperative group has been found to be both stimulating and stabilizing—stimulating to the unmotivated and stabilizing to the hyperactive and disturbed.

CONCLUSION

The use of heterogeneous cooperative groups is one of the most powerful tools available to educators to bring about the development of each student to her or his fullest potential. It provides a channel through which students with a variety of abilities and disabilities can be effectively integrated into the mainstream classroom, and a structure within which the other excellent techniques for dealing with the handicapped may be implemented.

REFERENCES

1. Johnson, David W., and Johnson, Roger T. *Learning Together and Alone*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1975.

2. Johnson, David W., and Johnson, Frank P. *Joining Together*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1975.

6. CREATIVITY FOR THE MENTALLY HANDICAPPED

by Donald R. Daugs

The author describes the teaching of creativity to the mentally handicapped student in a mainstream cooperative setting. Donald R. Daugs is an Associate Professor in the Department of Elementary Education, Utah State University, Logan.

Contrary to what many say, creativity can be taught. Contrary to what many say, all children are potentially creative. The elementary science setting offers some challenging opportunities for the teacher to facilitate the creative development of the educable mentally handicapped (EMH) child.

The creative process involves four distinct phases: The first consists of a challenge to the imagination; the second is primarily a mental, incubation–brainstorm–consider alternatives phase; the third is a do-it, try-it-out phase; and the final phase is an evaluation of the process and/or the product. The child with well-developed creative talent may be able to go through the above process under the stimulation of environmental circumstance only. Other children need the external stimulus of the teacher.

The creation of the "first" chocolate cake illustrates the steps involved. The setting is a fourth grade classroom. The participants are variously endowed with talents. Some students are mentally handicapped. The atmosphere is one of mutual admiration and a feeling that "No one of us is as smart as all of us."

The science unit is "Chocolate." Activities include observation, description, and investigation of the properties of chocolate. This is a multisensory experience for all students. None seems to be handicapped if the activities are relatively time-free. (1) There seems to be little relationship between the level of activity and traditional measures of intelligence. (2)

Experiments can vary from those as simple as tasting to those as complex as controlled experiments with rats on various chocolate diets. These various investigations may lead to the need for more information about chocolate. Books and related literature may be required. Class discussions should involve all students. Inferences about the desirability of chocolate made by the EMH child will be indistinguishable from those made by the normal child.

The situation has now progressed to phase one of the creative process—challenge to the imagination. Most children will have positive feelings about eating chocolate. Few of these children will have ever made a cake. The teacher sets the stage by asking, "How could we use chocolate in food?" The discussion is guided to include cake baking.

Phase two of the creativity process now moves to the mental process stage. This is the brainstorming–thinking–planning stage. Again, it is very evident that "No one of us is as smart as all of us."

Groups of four to six children should each devise a plan for a chocolate cake. This should be a relatively time-free, nonevaluative experience. It may be appropriate to allow a day or more of "research time" for children to consult parents or books on cake baking. However, they should not copy a recipe. Their cake is to be a first of a kind.

Upon completion of the plan, obtain the needed ingredients and do it. Ideally the children will do the mixing and baking.

The evaluation phase of the creative process in this case involves every child's sampling of each group's cake.

The Creative Process

Phase	Process	Source
1	Challenge to imagination	Materials and/or teacher
2	Mental incubation–brainstorm–consider alternatives	Student teams
3	Do it—carry out the planned experiment	Student teams
4	Evaluation of the experience	Student teams and teacher

Most elementary science curriculums include many situations that can be used to facilitate the creative process. Of the textbook series, STEM (Addison-Wesley Publishing Co.), Concepts in Science (Harcourt, Brace, Jovanovich, Inc.), MAPS (Houghton-Mifflin Co.), and the ESLI (Rand McNally & Co.) all encourage activity-oriented classroom environments. These ESS, SCIS, and SAPA II programs may be more easily adapted for a

student with a reading problem. *Often lacking in the above curriculums are instructional strategies that facilitate phase two of the creative process, the mental incubation-brainstorming-consider alternatives phase.* Also, most teachers are not accustomed to allowing students free time; thus, activities are fast paced and very prescribed. It must be kept in mind that a major role of the teacher in the creative situation is to manage time and make decisions about the use of incubatory techniques. It may be appropriate to allow phase two to extend over several periods or even weeks. The teacher will find little help in planning for phase two experiences in existing textbooks.

The Elementary School Sciences program (J.B. Lippincott Co.) has a format that is exemplary in that reminders to the teacher such as "a good place to stop" and "much work time" are included in the strategy. These cues seem to help program the creative process. This curriculum also includes many optional activities, which are a great source of ideas to extend a basic science curriculum into various creative experiences.

One of the advantages of this creative atmosphere is that the EMH child need not be treated differently. The child is part of a problem-solving team. Because children with mental handicaps do not have the same ability to adjust or to learn effectively in the usual classroom setting, the creativity model presents opportunities for the teacher to meet their special needs and abilities. The process is also very dependent on the cooperative attitude of all children involved.

REFERENCES

1. O'Brien, K.O., and Boerma, J. "Differential Relationships Between Creativity and Intelligence Under Two Conditions of Testing." Session 2.5, AERA, February 8, 1968.

2. Wallach, Michael, and Kogan, Nathan. *Modes of Thinking in Young Children.* New York: Holt, Rinehart, and Winston, Inc., 1965. Chapter 2.

7. AN AUDIO-TACTILE APPROACH TO SCIENCE EDUCATION FOR VISUALLY IMPAIRED STUDENTS

by Randall Harris

Suggestions for an audio-tactile approach, especially useful in instructing the visually impaired, but also applicable to teaching sighted individuals with weak visual learning modalities. Randall Harris is an Assistant Professor, University of Mississippi.

In conventional science education programs for normally sighted students, audiovisual aids have become commonplace. Over the years, classroom teachers have been encouraged to supplement their traditional demonstration-lecture approach with a wide variety of audiovisual aids. Governmental funding under the various Title programs, increased advertising by publishers of educational and scientific equipment, and teacher appeal have all contributed to a visually oriented approach to science education. Although much of what is taught in science classes involves three-dimensional objects and concepts, the presentation of the materials is often two-dimensional or visual, utilizing such aids as films, slides, textbooks, drawings, and diagrams.

THE AUDIO-TACTILE APPROACH

What is needed by visually impaired students is an audio-tactile approach to science education—one that utilizes, whenever possible, three-dimensional exemplars or models and verbal introductions and instructions. While the audio-tactile concept may, at first, seem like an expensive, time-consuming, backward step in science education, even the briefest review of pedagogic strategies will reveal that all students, handicapped and nonhandicapped, can benefit from an audio-tactile type of program. Even though visual aids are helpful and are often less expensive than a complicated laboratory demonstration, it must be remembered that not all students are able to learn from a visual presentation. It will also become evident that the purchase, construction, or development of a three-dimensionally oriented science education program is well within the abilities and budgets of most classroom teachers.

Victor Lowenfeld, a researcher concerned with the education of blind students, used the terms *visual* and *haptic* to identify types of persons who, whether they are blind or sighted, perceive their environment either "analytically" or "synthetically." According to Lowenfeld, the visual type is one who responds to the exterior aspects of objects and tends to perceive his/her environment as a whole. The haptic type, on the other hand, may never realize the whole and has a tendency to sort out parts and details from the environment. (4)

Through simple extrapolation, the point can be made that some youngsters learn best by physically examining an object while others learn best if they can form a mental or visual image of an object. Whether or not there is agreement with Lowenfeld's terminology, the point is that a three-dimensional tactile approach to science education can be beneficial to sighted students, who need to physically explore objects before they can fully comprehend them, as well as to blind students. The extensive use of visual aids, on the other hand, may not be beneficial to some sighted students, and it cannot be beneficial to blind students.

AUDIO ASPECTS

There are several reasons why the essential aspects of each science lesson should be presented verbally and recorded on audiotape. The primary reason is that both sighted and visually impaired students are able to learn from this type of a presentation. If students are required to gather information from textbooks, blind students will need expensive and bulky braille versions of the text. Both sighted and nonsighted students will be able to refer back to the tapes of those lessons they missed or did not understand fully. The classroom teacher can use tapes as a basis for examinations or make-up tests. Recorded lessons can also be used as a basis for the individualization that many teachers are now using in their science pro-

grams. Lessons presented in this fashion enable students to proceed at their own pace. Student involvement in making the recorded lessons can add a touch of excitement to a routine presentation.

It is not necessary to purchase a commercially produced science program, nor is it necessary to discard the old program. It is suggested, rather, because recording the essential aspects of lessons on audio-cassette tapes is an excellent and inexpensive way to begin to develop an audio-tactile program, that a tape recorder be brought into the classroom and used. Within one year, a skeletal program will begin to develop. New tapes can then be added as they are needed.

Eventually it will be necessary to acquire a number of tape recorders and head phones. It may also be practical to purchase multiple listening units which permit many students to listen simultaneously.

TACTILE ASPECTS

Giving a science program a tactile orientation rather than a visual orientation is neither difficult nor expensive. Many acceptable exemplars are currently available, but might require some simple alterations. Trips to the hardware store, the school storage room, the basement, or even the alley can produce many objects that can be used to develop scientific models for visually impaired children to explore.

Whenever possible, blind students should be offered actual objects, such as biological specimens, for examination. If specimens are not available or practical, then three-dimensional models can be used. The more realistic the material, the better the comprehension will be. Size is also an important consideration for model comprehension. If a model is being used, it should preferably be the same size as the object being presented. In many cases, however, a model will be used because the actual object is either too large or too small, such as the earth or an amoeba. Whenever scale models are necessary, a thorough explanation concerning the size change must be given.

A tactile program consists of more than just presenting touchable models to students. It is important to involve both sighted and nonsighted students in activities that force them to become physically involved and to actively interact with the material being presented. The following are a few examples of science projects that demand more than just passive participation:

- *Modeling* various birds and their habitats using clay;
- *Illustrating* the carbon cycle of a forest using papier-mâché;
- *Constructing* leaf-pressing books from old newspapers;
- *Designing* various constellations using paper stars;
- *Illustrating* the terrestrial food chain using found natural objects;
- *Designing* cloud formations using balls of cotton;
- *Building* bridge structures using plastic straws;
- *Constructing* papier-mâché volcanos and relief maps;
- *Constructing* a geodesic dome;
- *Building* a replica of a coral reef;
- *Illustrating* electromagnetic waves using iron filings and magnets;
- *Constructing* replicas of prehistoric tools.

The list of possible three-dimensional activities is endless. Getting the young learners actively involved in designing and building science projects is the key to successful programming for those individuals who are without sight.

EXPLAINING VISUAL CONCEPTS

Not all aspects of the science program can be explained using the tactile approach. There are a number of visual concepts such as light, color, reflections, etc., that cannot be easily demonstrated to children born blind. Some visual phenomena such as shadows can be demonstrated using props found in the classroom, but other visual phenomena such as light or color must be explained in a unique way. Shadows, as an example, can be demonstrated by directing a heat lamp on an object so that a shadow is created. The nonsighted students can locate the heat source, feel the warm side of the object, and trace the cooler shadowed area. Light, on the other hand, is more difficult to explain. Some very young children may be satisfied with the answer that there is light during the day and there is no light at night. Older children may need to know something about how light energy is given off by the sun. Still more inquisitive youngsters will need to be presented with theories about how light energy travels in waves, and to be given an explanation about the effect of energy waves on the retina of the eye. A series of experiments with various types of waves may be helpful in the understanding of light.

It is important for sighted teachers to realize that not all visual phenomena need to be explained in visual terms. For example, to a sighted person a sunset may be a panorama of brilliant colors set against a pale horizon. To

a blind person the sunset may announce the ending of a warm day. A blind person may notice the increased moisture on the grass from the dew or perceive different sounds from the birds in the trees. The sunset may mean an increased activity of mosquitoes or cooler breezes.

Intellectual maturity and curiosity will determine the type of explanation necessary for a young blind child to comprehend visual phenomena.

THE VISUALLY IMPAIRED POPULATION

One of the first steps necessary in the preparation of any educational program for blind and partially sighted students is the recognition that visually impaired individuals cannot all be lumped into one homogeneous group. A wide range of visual anomalies exists among those classified as blind, as well as among those classified as partially sighted.

The term *blindness*, often misused and misunderstood, denotes a spectrum of vision or the lack of it, ranging from total unresponsiveness to light to visual acuity that can be measured on an optometrist's "E" chart. Within the extremes of the term *blindness* are the abilities to distinguish lightness and darkness, to perceive movement just in front of the eyes, to distinguish form and color, and to travel freely without the use of a mobility aid.

The term *partially sighted* also includes a variety of visual impairments. Some children categorized as partially sighted are also part of the subcategory *low-vision*. Most low-vision children can read or can see objects when they are a few inches or a few feet away. Some low-vision students are able to use their vision for most school activities, while others need to use tactile or braille aids. Many visual anomalies will be apparent in the school setting. The types and severity of the impairments will determine the extent to which special aids will be required to augment regular science equipment.

ENVIRONMENTAL AND EQUIPMENT NEEDS

Depending upon the types of visual impairments involved, special environmental and equipment arrangements will need to be made. A blind student will need a table or desk that is large enough to hold a braille writer and whatever three-dimensional objects are to be examined. The desk or table should be located in an area that is easily accessible to three-dimensional exemplars. It should also be in an area that provides easy access in and out of the classroom. Some partially sighted students may need their desks facing away from the windows or intense glare. Generally, the visually impaired student will be able to adapt to the physical environment of most science rooms.

Special equipment will be needed by some youngsters. Partially sighted students might benefit from handheld or stand-mounted magnifiers. They might also be able to use overhead or slide projectors for some work. A microfiche or microfilm reader can provide assistance in some instances. Many types of optical aids are available without tremendous effort or expense.

A labelmaker, available with both braille and printed alphabets, is a piece of equipment that is inexpensive but essential to the classroom. Cassette tapes and special equipment or cabinets must have braille labels if the blind students are to be able to function freely in the classroom.

ALTERED TEACHING TECHNIQUES

If the audio-tactile approach to science education is to succeed, visually oriented teaching techniques must be de-emphasized. For example, many classroom teachers use the chalkboard to present quick explanations or to diagram problems. Visually impaired students need verbal explanations or responses.

Color coding is another example of a visual teaching technique. Teachers often correct papers in red or colored ink. Colorblind learners cannot see corrections or explanations that are in certain colors, and blind students obviously cannot benefit from color coding or written explanations.

Nonverbal actions or responses are also visually oriented techniques used extensively in the classroom. The blind student cannot respond to body language or nonverbal communication. A reassuring touch on the shoulder or an inflection in the voice is just as necessary to the nonsighted student as nonverbal communication is to the sighted student.

References to physical locations are also oriented toward the use of sight. For example, a teacher might ask a student to find a particular object "in the back of the room" or "on the bottom shelf" or possibly "in the storage cabinet." For the blind student, a storage cabinet can be a large place that could take a great deal of time to explore to find the desired object. As a result, directions need to be given in very specific terms.

Another example of inappropriate use of references

is the teacher who asks students to refer to the example at the top of the page. Braille editions of textbooks or workbooks are larger than printed versions and might not have the example at the top of the page. Care must be taken to communicate to visually impaired students in a way that permits them to comprehend and respond.

Nonsighted children are not handicapped because of their visual impairments, but rather they are handicapped because of the lack of opportunities available to them. Although an audio-tactile approach to science education will take time and effort to accomplish, it will be beneficial to all students, sighted as well as visually impaired, and it might provide opportunities to visually impaired children that were never before available.

REFERENCES

1. Harley, R.K., and Lawrence, G.A. *Visual Impairment in the Schools*. Springfield, Ill.: Charles C. Thomas, 1977.
2. Lisenco, Y. *Art Not by Eye*. New York: American Foundation for the Blind, 1972.
3. Lowenfeld, B. *Our Blind Children*. Springfield, Ill.: Charles C. Thomas, 1964.
4. Lowenfeld, V. *Creative and Mental Growth*. Third edition. New York: Macmillan, 1957.
5. Rieser, D. *Art and Science*. New York: Van Nostrand Reinhold Co., 1972.
6. Whitelaw, N. "Mainstreaming a Blind Child—One Classroom Teacher's Experience." *Journal of Visual Impairment and Blindness* 72: 153–154; 1978.

8. CHEMISTRY EXPERIMENTS FOR THE DEAF SECONDARY STUDENT: A VISUAL APPROACH

by Robert S. Menchel

A discussion of a chemistry program developed for the deaf with emphasis on visual learning. In addition to overcoming the handicapping condition resulting from loss of hearing, the program deals with the experimental handicaps resulting from previous lack of exposure to science. Robert S. Menchel is an Employment Analyst, National Technical Institute for the Deaf, Rochester, New York.

How do you teach a group of deaf secondary students chemistry when they have no background in the subject? When their vocabulary and reading levels are about fifth or sixth grade? This was the problem we faced when we decided to introduce laboratory chemistry to the deaf high school students in a residential school. We knew that hands-on experiments were very important to supplement their classroom reading. However, the chemistry workbooks available were not suitable because of the problems we faced with these deaf children. They had—

1. No chemistry background from elementary school through the first or second year of secondary school.
2. No understanding of the chemistry terminology used in available workbooks.
3. A lack of understanding of how to record and analyze data.
4. A lower reading level than that used in available high school chemistry workbooks.
5. A very limited time period for laboratory work due to conflicting schedules during the school year.

In addition:

1. The science teachers did not have a strong background in chemistry.
2. The limited amount of chemicals available in the laboratory required that we bring in some supplies for each class.

At this point I would like to explain how all this came about. In the fall of 1970 a program was started by several engineers and scientists at Kodak and Xerox to bring science to inner city schools on a voluntary basis. The program grew from one in which a few people paid the cost out of their own pocket to a company-supported project. In 1971 Xerox Corporation took over the responsibility for the program and fully funded it, paying for supplies and travel expenses. In the fall of 1971 I requested and was granted permission to bring the program to the deaf children in Rochester, New York. Thus, in 1971 for the first time the deaf children in that city were exposed to a deaf scientist! Over the years we built up a good program covering basic science. We were willing to try anything. All our equipment was homemade; we used the tin can–rubber band approach. There were several reasons why we did this rather than use commercial equipment. The first was that in order for the program to remain in a school once it had been started, the cost of equipment replacement must be low. Second, and more important, we wanted the children to perform the experiments themselves, run home, and show Mom and Dad. If the experiments required expensive equipment not found around the average classroom or home, their interest would shortly die out.

Therefore, when we were asked in the spring of 1979 if we could make up a chemistry laboratory course for deaf secondary school students, we had already had a lot of experience working with them. We decided that a workbook was needed and that it should be one that the deaf student could use and understand. We decided to write our own workbook, taking into account the limitations described before. The book was based on the following considerations:

1. It should be interesting.
2. It should be easy to read and geared to the reading level of the average deaf student.
3. It should include lots of pictures since a deaf person's eyes are the most important learning tool he/she has.
4. It should cover the most important aspects of chemistry.
5. Experiments should be short and to the point.

After searching through a great many chemistry books, we decided on twelve experiments. These twelve experiments were to cover the school year on a bimonthly

visit basis. We also designed some experiments that were termed "fun experiments with chemistry."

In writing the workbook, we tried to use as many pictures as possible. We also tried through the use of pictures to describe what was happening during a process or to show how to perform an operation.

During the course of writing this workbook we found that students could not be given large amounts of information at one time. Procedures had to be written in a step-by-step manner, as shown in the sample below.

Each experiment was laid out following this format:

1. *Equipment needed.* All laboratory equipment, such as beakers, and their sizes, amounts, etc., are listed.
2. *Chemicals needed.* All chemicals, along with their chemical symbols, are listed.
3. *Safety rules.* Any warnings about dangers in this experiment are listed. We always included a statement to review safety rules.
4. *Introduction.* A brief introduction to what the experiment is all about is given.
5. *Procedure.* A step-by-step description of how to perform the experiment follows.

We often added information to the experiment to help the student understand what was happening. We also added definitions of words where we felt it was necessary, as seen in this example:

... most materials expand (grow bigger) when heated, and contract (grow smaller) when cooled.

The purpose of this workbook is not to give a complete course in chemistry, but rather to introduce deaf students to the chemistry laboratory, and to allow them to observe, record, and learn how to use the scientific method. The workbook also supplements what they read in class by allowing them to observe the chemical procedure. We have found that with this kind of introduction, many students have become interested in following a scientific career. In other words we make chemistry fun and interesting.

SAMPLE EXPERIMENT—SOLUBILITY

Equipment Needed

3 beakers (each large enough to hold 100 ml of water)
thermometer
balance

Chemicals Needed

potassium chlorate
potassium nitrate
sodium chloride

Safety

Review Experiment #6 on temperature.

Introduction

If a lump of sugar is dropped into a beaker containing water, the lump slowly disappears. The sugar is said to *dissolve* in the water. We could look at a drop of this liquid very carefully with a microscope, but we would not see the dissolved sugar. We can add more sugar and it, too, will dissolve. But if we continue to add sugar, we finally reach a point where no more sugar will dissolve in the liquid. We then say that the solution is *saturated.*

By tasting the liquid, we can tell that there is sugar in it. The molecules of sugar have become mixed with the molecules of water so that the liquid tastes sweet. Also—and this is an important fact to notice—the same degree (amount) of sweetness will be tasted in all parts of the liquid. A mixture like this is called a *solution.*

Definitions:

A *solution* is a *homogeneous* mixture of two or more substances, the *composition* of which may be varied (changed), but only to a certain point.

homogeneous—the same throughout.

composition—the amount of each substance used to make the new substance—here, the amounts of sugar and of water used to make the solution.

The dissolving medium—in our example, water—is called the *solvent.*

The substance dissolved—in our example, sugar—is called the *solute.*

Not all substances form true solutions in water. If we mix clay with water, very little clay actually dissolves. The particles of clay are huge compared to molecules; we would see them with a microscope. A very turbid (cloudy) and *heterogeneous* (look this word up in a dictionary) mixture called a *suspension* results.

Matter may exist in three states: solid, liquid, and gas. Therefore, we may expect to have nine different types of solutions. These are shown in the table below.

TYPES OF SOLUTIONS

	Solute	Solvent	Example
1.	gas	gas	air
2.	gas	liquid	soda water
3.	gas	solid	hydrogen in palladium
4.	liquid	gas	water vapor in air
5.	liquid	liquid	alcohol in water
6.	liquid	solid	mercury in copper

	Solute	Solvent	Example
7.	solid	gas	sulfur vapor in air
8.	solid	liquid	sugar in water
9.	solid	solid	copper in nickel

All mixtures of gases are solutions because they consist of homogeneous mixtures of molecules. Solutions of a solid in a liquid are by far the most common.

We may think of the solution process as being *reversible*. Consider again the sugar lump in water (Fig. 29). As the sugar dissolves, sugar molecules break away from the crystals of sugar in the lump and enter the water. In water, they bounce around at random. Some of the dissolved sugar molecules may touch the undissolved sugar and again become part of the sugar crystal structure.

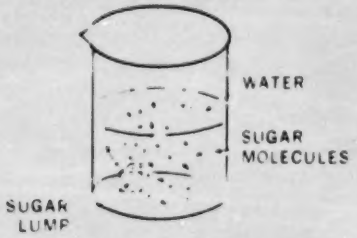


Figure 29

Thus, the solution process consists of the act of *dissolving* and the act of *crystallizing*.

When we first put the sugar into the water, molecules leave the crystal structure and diffuse (move) throughout the water. As the solution *concentration* (or number of sugar molecules per unit volume of solution) becomes greater, the reversal process begins. The rate at which sugar crystals rebuild increases as the concentration of the sugar solution increases. Eventually, if undissolved sugar remains in the beaker, sugar crystals rebuild as fast as they dissolve. Then, we say that the solution is *saturated* and that an equilibrium exists between the undissolved sugar and the dissolved sugar in the water.

Definitions:

Solution equilibrium is the physical state in which the processes of dissolving and crystallizing of a solute *occur at equal rates.*

A *saturated solution* is one in which the dissolved and undissolved solutes are in equilibrium.

Procedure

1. Take a piece of filter paper. Place it on the dial balance and dial the knob to 50 grams. Add small amounts of *potassium chlorate* until the balance needle swings up toward the zero mark.
2. You now have approximately 50 g of potassium chlorate on the filter paper. Determine the *precise* weight by turning the dial until the needle on the balance is exactly level. Record the weight on your worksheet (Part C).
3. Add 100 ml of water to a beaker. Record the volume on your worksheet (Part A).
4. Measure and record the temperature of the water on your worksheet (Part B). *Note*: Make sure that the temperature of the water is the same (to within 3°C) for each solubility test.
5. Now add small amounts of potassium chlorate to the beaker. Stir each time you add some chemical. Continue to add chemical until no more will dissolve.
6. Now, weigh the filter paper and the remainder of the chemical. Record this weight on your worksheet (Part D). The amount of chemical dissolved in the beaker of water is the difference in weight between the amount of chemical at the start of the experiment and the amount left on the filter paper after step 5 is completed.
7. Repeat the procedure two more times, but use sodium chloride and potassium nitrate as the chemicals.

WORKSHEET

	Sample Calculation	Beaker 1 Potassium Chlorate	Beaker 2 Sodium Chloride	Beaker 3 Potassium Nitrate
A. Volume of water in beaker	100 ml			
B. Temperature of water	25°C			
C. Weight of filter paper and chemical at start	53.4 g			
D. Weight of filter paper and chemical at end of steps	46.2 g			
E. Total grams of chemical dissolved in water, C - D	7.2 g			
F. Concentration in g ml, E A	.072 g/ml			

Sample Calculation

Part E—total grams dissolved = C - D = 53.4 g - 46.2 g = 7.2 g

Part F concentration = E A = 7.2 g 100 ml = .072 g ml

9. THE MAN, THE CHILD, AND THE FLOWER (LABORATORY SCIENCE FOR THE HANDICAPPED STUDENT: TEACHING MAINSTREAM STRATEGIES)

by Doris E. Hadary

Illustrates how the multisensory approach can be combined with creativity and art to produce what might be called the total experience approach *for both the handicapped and the regular student. Doris E. Hadary is Professor of Chemistry, The American University, Washington, D.C.*

On the outskirts of a village near Jinja in Uganda, Africa, there was a small black child; an old, wrinkled, delicate man with a wise air about him; and a lone weed with a purple flower. They were surrounded by a vast emptiness except for a few clusters of thatched huts in the distance.

The child was maimed, his little leg twisted; the little, wrinkled, wise-looking old man was blind. Slowly the young child whose steps were still uncertain guided the man along the dry, empty field, loving the presence of the sun, the sky, and the breeze which cooled their skin.

Suddenly the child let go of the hand he was guiding, ran to the flower, and sat down with great excitement and curiosity to observe—he looked, he felt, he touched, he put his face to it and called to his companion to "Come see." The friend found his way to the child and the flower. The child, his whole being engulfed in excitement, cried, "It has a dark beautiful color—purple, on the inside it is yellow with some little threads, the other parts are green—and, grandpa, you wouldn't believe it, it is coming from the earth. What is it? How did it get there?"

My presence was felt. The man turned toward me and, with his gentle philosophical smile, said, "You see, the beauty of childhood lies in the curiosity of the child and excitement in the discovery of the wonders of the world. It is there in the womb ready to unfold in birth."

It is within the context of seeing the inborn qualities and potential of the child and of knowing the content and nature of science that we find our strategies for teaching science—a teaching strategy that addresses itself to the sensory deficiencies of the blind, deaf, emotionally disturbed, and otherwise handicapped children based on a knowledge of content and a realization of the excitement therein.

TO BELIEVE

The prerequisite to an effective science teaching strategy that enhances the education of all children is "to believe"—to believe that science is a powerful and necessary tool in fulfilling each child's potential—in giving the child a mechanism by which to cope with the forces in the world she or he lives in; to believe that science is a means of achieving the goals of intellectual, conceptual, and cognitive development; to believe in the ability of science to bring about acceptance of human beings as human beings and to use science and art as a means of introducing a true set of values that brings out the innermost needs of an individual—in the teacher as well as the children; to believe that science shows the way to an educational process in which development of the total being is achieved by stressing the abilities to question, to discover, to seek answers, to find form and order, to rethink, and to restructure and find new relationships through experiences in science and art in order that the child's creative abilities can unfold.

Handicapped children many times experience school as frustrating and painful, and classroom teachers find them difficult to teach and manage. While many remedial approaches have been reported to help these pupils, the use of science as a motivator for learning has been neglected. This is a distressing fact. Science not only has a natural appeal to children, but also it fulfills the need of the child for a rational, logical explanation and control over a confusing world. The knowledge of, and experimental approach to, science helps these pupils replace their magical thinking and omnipotent fantasies with general truth and laws. Science deals with reality—not fantasy. It facilitates cause-and-effect observations of behavior, separation of facts from feelings, and the teaching of a problem-solving approach to conflict. It provides the child with positive feedback such as, "I can learn!" or, "I'm not dumb or stupid!" or, "Learning is interesting!" or, as one pupil said, "I didn't even know I liked science, but now look at me, I'm a scientist!" It appears that science and psychotherapy have many similar goals. People in some cultures would attribute a tidal wave to their god's personal retribution for something they did to offend her or him. Emotionally troubled children similarly live in a world of magic, guilt, and confusion. To

master this stressful world, these pupils need to understand that life events do not happen because they are bad or powerful, but rather that these events are related to cause-and-effect reality principles and that they can be controlled. Laboratory science, by giving pupils autonomy in conducting their own explorations and investigations, can perhaps be used to help these pupils gain self-confidence and self-esteem, and to learn to live more comfortably with themselves and their world.

HOW?

Multisensory Approach

The teachers of the new era of teaching handicapped children in a mainstream setting must have a new and full sensitivity for teaching. They address all senses of the child simultaneously. Through their teaching strategies they relate to the child who cannot see by means of feel and sound, to the child who cannot hear by means of visual and tactile stimuli. Their approaches must provide a pattern of objectives for the emotionally disturbed child.

The new image of the teacher demanded by mainstreaming provides an exciting challenge to the teacher: to never lose, for one moment, the awareness of the handicapped—or "normal"—children in the class; to reach out to all of them, according to each child's limitations and abilities; to compensate through teaching strategies for the deficiencies of the handicapped child. It is essential for the teacher to address the abilities rather than the disabilities of handicapped children. Studies have shown that teacher attitudes and expectations are reflected in the child's academic performance and level of achievement. (2)

The nature of the mainstreaming science and art approach helps the teacher to fulfill this new mainstreaming role and to function sensitively and effectively with all children. An important key to successful implementation of teaching strategies is to recognize and develop a nonfragmented, composite, multifaceted strategy engulfing multisensory, multilevel, and multimaterial approaches. This total approach as a unified whole reaches and provides a rich learning experience for all the children at the same time.

Much of what is written about the education of handicapped children reflects the philosophical position of academics and is usually couched in sweeping generalizations. These generalizations are often of little value to the classroom teachers who are faced with the demand to promote the development of children on a day-to-day basis of involvement. It is with this in mind that the following example is presented as an answer to how to meet this demand.

The following lesson, *A Lesson in Optics* is an example of a lesson that has been adapted for use in a mainstream setting which may include blind, deaf, emotionally disturbed, and otherwise handicapped students.

A LESSON IN OPTICS

Exploring a Beam of Light
Adaptations by Robert Haushalter

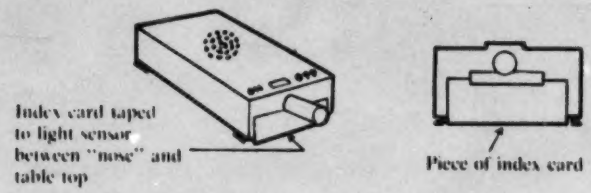
Materials for Each Child

Materials marked with an asterisk (*) are contained in Elementary Science Study (E.S.S.) Optics (McGraw-Hill). Materials designated by A.P.H. are available from the American Printing House for the Blind, Louisville, Kentucky.

- *E.S.S. light source box
- 100-watt bulb
- extension cord
- 16" x 20" double-weight mounting board (available at local art stores)
- 4 sheets of 14" x 17" newsprint (available at local art stores)
- 1/2" masking tape
- 10 thumb tacks
- 1/2" x 8" wooden dowel or (first grade) pencil
- two 3" x 3" pieces of cardboard (from a shoe box)
- A.P.H. light sensor (for the blind child)
- language cards for the deaf—beam of light
  mirror
  shadow
- screen mesh—14" x 16" (available at local hardware stores)
- *2 E.S.S. metal mirrors
- *4 E.S.S. mirror stands
- *4 plain masks (# 6)—4" x 6" pieces of black paper with a slit on each side to be mounted on brass fasteners (see page 48)
- 8 brass fasteners
- one 3" x 5" index card (available at local art stores)
- cardboard gingerbread man cut-out (6" high)
- crayon
- 8" x 20" mounting board (available at local art stores)
- mat knife or xacto knife (for use by teacher only) (available at local art stores)
- A.P.H. braille ruler
- various simple shapes—scissors, tweezers, etc.

Advance Preparation

Tape the 16" x 20" piece of double-weight mounting board to a table top or desk. Allow at least a 4" clearance between the edges of the mounting board and the table top edges. This 4" area is for the A.P.H. light sensor. Place tape on the *bottom* of the mounting board only. (Tape on top of the mounting board edges will impede free movement of the A.P.H. light sensor.) Cut a piece of the 3" x 5" index card so that it fits under the light sensor nose and is flush with the table top. (Save the index card.)

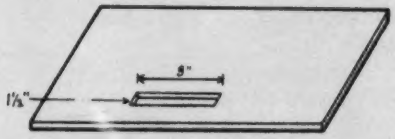


This allows the light sensor to slide more freely along the mounting board edges. Without the piece of index card, the "rubber shoes" of the light sensor tend to catch the mounting board edge, causing the light sensor to slide unevenly.

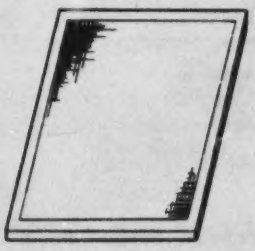
Tape the E.S.S. light source box to the table top against the back edge of the mounting board. This is to prevent the ray of light from shifting if the box is bumped.

Tape the light source top to the sides of the box. Allow as little light as possible to escape. The slightest amount of light can be detected by the A.P.H. light sensor.

Using the mat knife or xacto knife, cut a 1-1/2" x 8" opening about 1/2" up from the bottom edge of the 8" x 20" piece of mounting board (small mounting board).

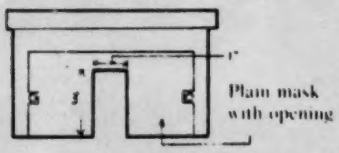


Tape the 14" x 18" screen mesh to the 16" x 20" mounting board.

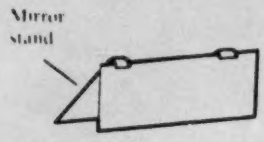


Place three of the plain black masks over the two side openings and the back opening, using the brass fasteners, so that no light is emitted.

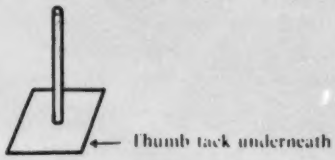
Cut a 1" x 3" opening in the center of the remaining plain mask and place it over the front opening.



Tape two mirror stands to each mirror.



Using a thumb tack, the 3" x 3" piece of cardboard, and the 1/2" x 8" dowel or (first grade) pencil, push the thumb tack through the center of the cardboard and into the dowel end.



Tape the newsprint (14" x 17") to the mounting board/screen mesh system.

Place the 8" x 20" piece of mounting board on top of the newsprint. Push it up against the light source box with the side having the rectangular cutout nearest the light sensor.

Press the remaining thumb tacks into the mounting board in the righthand corner farthest from the light source box.

Suggestions

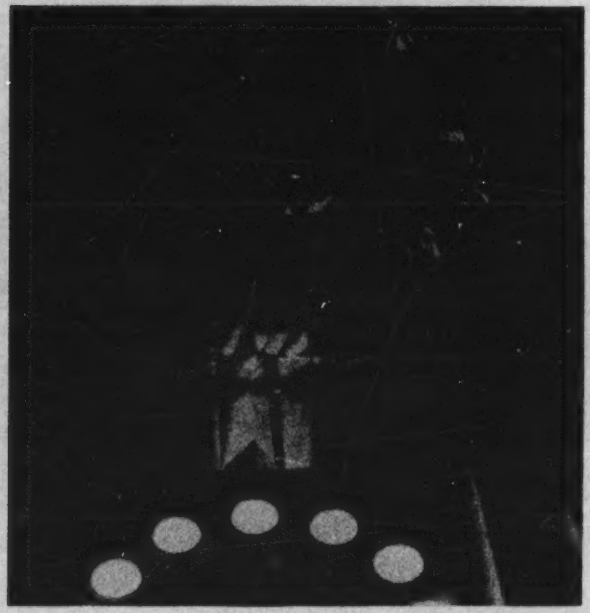
Give the children a chance to explore the optics setup. Have the blind child set up the light sensor on the front side of the mounting board with its nose facing the light source. Encourage the visually impaired child to slide the light sensor from left to right, starting from the left corner of the mounting board. This should be repeated a number of times so that the child becomes familiar with the sound pattern produced as well as the interplay between the light sensor and the mounting board.

Question: "What causes the pitch to go higher and lower?" Encourage the child to press a thumb tack into the mounting board, marking where the pitch of the light sensor makes an abrupt or sudden change (first higher, then lower). Make sure s/he realizes that evidence of the fringe or edge of the light ray is denoted by the *sharp*

change in pitch, not by the gradual increase or decrease heard as the light sensor nears the ray's edge. Once the two thumb tacks (outlining the ray) are in position, have the child measure the width of the light beam by placing a braille ruler against the thumb tacks and measuring the distance between the two.

Question: "How wide is the light beam or path of the light?" Have the child line the A.P.H. light sensor along the front edge of the smaller mounting board. Repeat the previous procedure. Mark and measure the width of the light beam. The thumb tacks should be pressed within the opening of the small mounting board.

Question: "What happens to the light ray as the distance between the light sensor and the light source increases?" "What happens to the sound from the light sensor?" Have the small mounting board removed. Now have the child plot the width of the opening of the light source. Encourage the child to draw two lines that will show the edges of the light ray extending from the light source to the edge of the large mounting board. If s/he does not devise her or his own system, suggest that s/he line the ruler up against the three thumb tacks on either side of the light beam's path and draw a line (using a crayon) between them. There should be two raised lines (because of the screen mesh) on the newsprint outlining the path of the light ray. The thumb tacks can be removed at this time.



Shadows

Once the child has marked the outline of the light ray, place the erect pencil probe in the path of light.

Explain to the child that an object is blocking part of the light beam leading to the light sensor.

Question: "How can you find the area within the light ray path that is being blocked by the probe?" The child should set out to plot the dark area within the light beam using the light sensor in the same manner as before. Some children will be able to distinguish the left and right edges of the dark area (and will mark two points), others won't (and will mark only one). The thicker the probe, the better. Try to have the child plot the edges of the dark area. After the dark area has been plotted, have the child feel the probe. Explain to her or him that the dark area was created by the shadow cast by the probe. Once both edges of the shadow have been marked, have her or him measure the shadow's width.

Question: "What causes the difference in size between the pencil and its shadow (image)?" Have the child place the small mounting board into position again. Place the probe stick (pencil) directly in front of the light source opening. The child should plot the width of the probe stick's shadow from the two established distances of the large and small mounting boards. Suggest that the outline of the probe's shadow be plotted using the ruler and crayon.

Next, fold the index card into a "V" shape or tee-pee. Hand it to the child and have her or him place it in the light beam path. Encourage her or him to locate its

shadow and plot it with the thumb tacks. Then have the child alter the position of the tee-pee. "What happens to its shadow?"

Have the child use other objects (i.e., scissors, tweezers, etc.) and see if s/he can plot their shadows.

SCIENCE AND ART

In our program an integral part of the science lesson is an art lesson that is based on the assumption that both disciplines share common learning experiences and procedures. Behaviors involved in science and art reinforce each other and allow the child to internalize and communicate her or his experience in a creative manner. Science reveals the richness of the natural world. Art helps the child to shape her or his understanding of that richness with her or his own hands and mind. With the strategies and sample experiments discussed, the goal of providing a high-level, appropriate education for handicapped pupils through science in the regular classroom—without taking place at the expense of others, but, on the contrary, enriching the education of all others—becomes a realistic and challenging possibility.

REFERENCES

1. *Fulfillment of Human Potential.* Film with instructor's guide by Doris E. Hadary, The American University, Washington, D.C. Distributed by McGraw-Hill, Del Mar Calif.

2. Hadary, Doris E., and Cohen, Susan Hadary. *Laboratory Science and Art for Blind, Deaf, and Emotionally Disturbed Children—A Mainstreaming Approach.* Baltimore: University Park Press, 1978.

3. *Mainstreaming Techniques: Life Science and Art.* Film with instructor's guide by Doris E. Hadary, The American University, Washington, D.C. Distributed by McGraw-Hill, Del Mar, Calif.

4. *Special Education Techniques: Laboratory Science and Art.* Film with instructor's guide by Doris E. Hadary, The American University, Washington, D.C. Distributed by McGraw-Hill, Del Mar, Calif.

10. CONCEPT ANALYSIS: A MODEL FOR TEACHING BASIC SCIENCE CONCEPTS TO INTELLECTUALLY HANDICAPPED STUDENTS

by Jack T. Cole, Margie K. Kitano, and Lewis M. Brown

The authors develop the concept analysis model in a clear and meaningful way. Further, they offer it as a viable approach to the problem of successfully teaching abstract science concepts to the intellectually handicapped student (as well as the regular student) because this technique fosters concept formation, thinking ability, logical deduction, and creative problem solving. *Jack T. Cole is Assistant Professor of Special Education, Department of Educational Specialties, New Mexico State University, Las Cruces; Margie K. Kitano is Assistant Professor of Early Childhood Education and Special Education, Department of Educational Specialties, New Mexico State University, Las Cruces; and Lewis M. Brown is Assistant Professor of Geology, Department of Earth Sciences, Lake Superior State College, Sault Sainte Marie, Michigan.*

In a position statement on science education for the future, the National Science Teachers Association suggested that the goal of science education should be to develop scientifically literate citizens. (8) This goal is equally relevant for intellectually handicapped children and youth at a more fundamental level. Due to a combination of limited capacity and experience-based deficiencies, many handicapped youngsters have had inadequate interactions with the physical environment. (5) Such lack of experience limits these children's informational repertoire and, hence, their ability to solve the problems that confront them in school and later life. Curriculums for intellectually handicapped students in particular should include an emphasis on basic science concepts since for these students knowledge of the environment is essential for survival. Systematic learning about the physical environment is critical, for example, so that problems with safety (e.g., touching something hot) or problems with health (e.g., having an inadequate diet) can be avoided. (5) In addition, basic science concepts that help familiarize intellectually handicapped students with the physical world are necessary in building a foundation for the mastery of vocational skills (e.g., cooking, raising plants and animals, using tools and machines).

A lingering problem has been the lack of methods or models for teaching abstract science concepts to the intellectually handicapped. Such students often have difficulty learning these abstract concepts due to their lower level of cognitive functioning. These needs have not been met by nationally funded science programs such as Science Curriculum Improvement Study (SCIS), Elementary Science Study (ESS), Science—A Process Approach (SAPA), and MINNEMAST, all of which stress content and process to varying degress and are designed for classrooms containing nonhandicapped children, with the exception is SCIS, which was modified for use with the visually impaired.

A strategy that has great potential for use in teaching science concepts to intellectually handicapped students is *concept analysis*. This technique is particularly useful with remedial learners in the areas of concept formation, thinking ability, logical deduction, and creative problem solving. For this reason, the four aspects of the goals of science education—knowledge, skills, understanding, and propensities (7)—are well addressed through the use of concept analysis.

This teaching technique concerns itself with identifying the critical and noncritical attributes of the concept to be taught. Models using concept analysis have been developed to enhance the processes of generalization and discrimination. (1, 6, 9) The differentiation theory of Gibson (2) and Gibson and Levin (3) and the attention theory of Zeaman and House (11) and Zeaman (10) support the use of concept analysis principles. Both theories point to the importance of enhancing the relative stimulus attributes, a principle maximized by comparison of critical and noncritical features in concept analysis.

The authors advocate the model of concept analysis illustrated in Figure 1 for developing a basic science curriculum oriented toward intellectually handicapped students. To utilize this model, the teacher must develop an instructional plan based on five phases:

I. Identify the Concept. In this first phase, the teacher simply identifies the concept(s) to be taught. For example, some basic science concepts important for

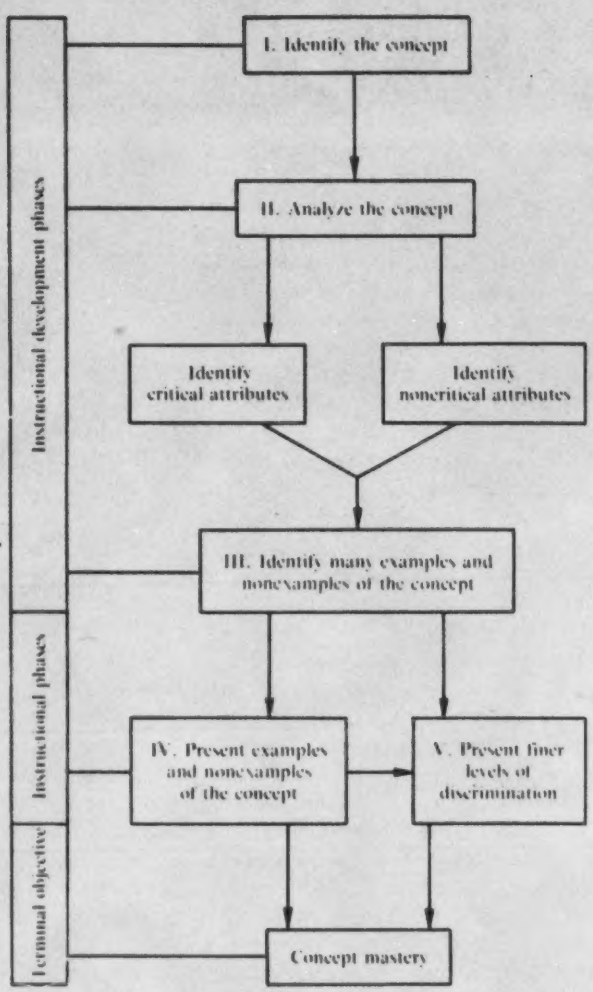

Instructional development phases
Instructional phases
Terminal objective
I. Identify the concept
II. Analyze the concept
Identify critical attributes
Identify noncritical attributes
III. Identify many examples and nonexamples of the concept
IV. Present examples and nonexamples of the concept
V. Present finer levels of discrimination
Concept mastery

Figure 1. Concept analysis model

intellectually handicapped students might include living, work, energy, growth, environment, mammal, shape, and reptile.

II. Analyze the Concept. This phase actually consists of two steps: the identification of critical and of noncritical attributes. Critical attributes have characteristics that, taken together as a set, differentiate a concept from other concepts. (4) The entire set of attributes must be present to define a particular concept.

Using *mammal* as a concept example, the critical attributes might be:

1. Body covered by hair (fur or wool)
2. Mammary glands
3. Lungs
4. Four limbs (arms and legs, flippers, paddles)
5. Gives birth to living young (except for duckbilled platypus and spiney anteater)
6. Two parents
7. Capable of movement

Noncritical attributes, of course, have characteristics that do not differentiate a concept from other concepts. While the list of noncritical attributes could be infinite, it is essential for the teacher to identify those that would serve to confuse the mentally handicapped learner. At first glance, many attributes appear to be critical to a concept. However, closer examination will reveal that they are common to more than one concept, are no part of the critical set defining the concept, and, consequently, do not serve to accurately differentiate between concepts.

Again using *mammal* as a concept example, some noncritical attributes might be:

1. Color
2. Sex
3. Size
4. Age
5. Number of parents after birth
6. Dietary habits
7. Life span

III. Identify Many Examples and Nonexamples of the Concept. Examples of the concept contain the set of critical attributes while nonexamples lack the set of critical attributes.

For *mammal*, examples of the concept could include:

1. Man
2. Cat
3. Dog
4. Monkey
5. Cow
6. Horse
7. Mouse

For *mammal*, nonexamples of the concept could include:

1. Snake
2. Duck
3. Fish
4. Insect
5. Lizard
6. Frog
7. Shellfish

IV. Present Examples and Nonexamples of the Concept. The actual presentation of examples and nonexamples to the intellectually handicapped student should utilize a variety of media. For *mammal*, live

examples and nonexamples as well as ones depicted in movies, photographs, and drawings could be used. If drawings are to be used, they should be as realistic as possible.

Examples of the concept teach the student to generalize to other incidents within the same concept, while nonexamples teach the student to discriminate between differing concepts. It is especially important with intellectually handicapped students to present a large number of examples in a variety of situations. These situations should also include noncritical concept attributes. Examples presented for the concept of *mammal* might be *man* and *boy*, which would account for the noncritical attributes of size and age. Similarly, the presentation of several *men* and *women* would account for the noncritical attributes of sex and number. In order to avoid confusing the mentally handicapped learner, it is recommended that mastery of the examples be established before the introduction of the nonexamples.

V. Present Finer Levels of Discrimination. Examples and nonexamples should be presented in a manner that calls for increasingly finer levels of discrimination by the learner. Essentially what might be termed a *funnel approach* is used. Initially, the difference between the example and the nonexample should be very clear. It would be a good idea to contrast *man* (example) with *rock* (nonexample). As the student masters these clear contrasts, finer discrimination will be required. For instance, *anteater* (example) would be contrasted with *armadillo* (nonexample).

In summary, the concept analysis model presented by the authors provides a process by which teachers can systematically develop and teach science concepts to intellectually handicapped students in a manner that is easy to implement, effective as a teaching tool, economical in terms of time needed to prepare units, and financially inexpensive.

REFERENCES

1. Becker, W.C.; Engelmann, S., and Thomas, D.R. *Teaching 2: Cognitive Learning and Instruction.* Chicago: Science Research Associates, 1975.

2. Gibson, E.J. *Principles of Perceptual Learning and Development.* New York: Appleton-Century-Crofts, 1969.

3. _____ , and Levin, H. *The Psychology of Reading.* Cambridge, Mass.: The MIT Press, 1975.

4. Hertlein, F.J.C., and Whitney, R.A. "Concept Analysis: An Approach to Instructional Programming." *Breakthrough* 2: 2-4; 1975.

5. Hewett, F.M. *Education of Exceptional Learners.* Boston: Allyn & Bacon, Inc., 1974.

6. Markle, S.M., and Tiemann, P.W. *Really Understanding Concepts: Or in Frumious Pursuit of the Jabberwock.* Champaign, Ill.: Stipes Publishing Co., 1970.

7. Martin, M. *Concepts of Science Education.* Glenview, Ill.: Scott Foresman Co., 1972.

8. National Science Teachers Association. *Science Teacher* 38(8): 46-51; 1971.

9. Thiagarajan, S.; Semmel, D.; and Semmel, M. *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook.* Bloomington, Ind.: Council for Exceptional Children, 1974.

10. Zeaman, D. "One Programmatic Approach to Retardation." *The Experimental Psychology of Mental Retardation.* (Edited by D.K. Routh.) Chicago: Aldine, 1973.

11. _____ , and House, B.J. "The Role of Attention in Retardate Discrimination Learning." *Handbook of Mental Deficiency.* (Edited by N.R. Ellis.) New York: McGraw-Hill, 1963.

11. THE VISUALLY IMPAIRED HIGH SCHOOL STUDENT CAN *SEE* HER OR HIS PROGRESS IN THE REGULAR SCIENCE CLASSROOM

by Mary Ann Ovnik

In an application of the team approach, the author describes a mainstream science program in which the regular classroom teacher and the special resource teacher work together with the student and her or his parents to produce and modify a data-based science program, enabling blind as well as sighted students to "see" their progress. Mary Ann Ovnik is a science teacher and Special Education Resource Consultant, Lyons Township High School, South Campus, Western Springs, Illinois.

"Do you see?" asked the science teacher. Every student in the class nodded affirmatively. Jane and Joseph, nodding with the group, each put down a stylus and slate. The teacher enthusiastically went on with the lesson, and the students were instructed to go to their laboratory stations and work on the inquiry planned for that day. Jane and Joseph were not laboratory partners, but they did confer and share materials. They were free to do so during the lab period and during the time they spent in the Resource Room. One was only aware of their visual impairment when they proceeded to cross the room with braille notes in hand. Jane and Joseph were both blind students, and this incident took place in a biology class at Edwin G. Foreman High School, Chicago, Illinois, in the mid-1960's.

Mainstreaming has been carried on in the Chicago Public School System since 1900. Chicago and its suburban school systems have planned for and provided suitable mainstream education for the visually handicapped. Special education services are available and used as resource assistance to these students. Visually impaired students are programmed into regular education classes according to their intellectual ability. Individualization is carried out to make the transition smooth and to give each student an opportunity to reach full intellectual potential.

Rules and Regulations to Govern the Administration and Operation of Special Education specifies that a student is eligible when "visual impairment is such that the child cannot develop his or her education without special services and materials." (3) In 1965, the General Assembly of the State of Illinois outlined the Services for the Visually Impaired in Article 14 of the School Code (14-11.01). This agency, located in Chicago, coordinated the materials needed for teaching visually impaired students in mainstream settings. Materials such as braille, large print, and recorded textbooks were made available to each school servicing an eligible student. At first this service was offered only for elementary students; it was later extended to the secondary level, and since July 1975, post-secondary services have been offered.

Resource assistance is available in each school serving a visually impaired student. In the City of Chicago, there are two secondary-level Braille Centers, and visually impaired students may elect to go to either of the Center Schools or to the home school in their community. Bus service is available.

At the Braille Center a braille resource teacher is assigned to assist the students. Visually impaired students are assigned to the Resource Room instead of to study halls. The students, mainstreamed for all classes, are given assistance by peer tutoring groups as well. The resource teacher's role includes assisting the academic teachers in preparing specialized classroom materials, and instructing them in preparing suitable teaching aids (i.e., raised line drawings, etc.). The tape recorder is the handy helper of both student and teacher.

If the student elects to attend her or his own home school, provision is made to supply the student with an itinerant teacher who schedules visits according to student need. During these visits the itinerant teacher assists the classroom teachers and the student through consultation and/or direct service.

We no longer question, "Should we mainstream?" The question now is, "How do we mainstream most effectively?" The science teacher, who has as a major concern the imparting of scientific knowledge, may find the presence of a visually handicapped student a real challenge. While the teacher's immediate thoughts may go to alterations to the curriculum, developing new materials is not the answer. What is used to teach sighted people can also be used to teach those without eyesight. *Adaptation* of materials is the real possibility.

Targeting behavior through data-based program-

ming may be the answer for the science teacher. What exactly is demanded of any student to successfully complete this particular course? What types of materials will this handicapped student use to adapt the curriculum to her or his need? Braille texts, typewriters in the classroom, raised line illustrations, taped materials, and a peer tutor as a laboratory partner who has been specially selected not only for ability but also for personality are just a few of the alternatives that may be used. What skills and/or behaviors will the student need to improve or definitely possess before being admitted to the course? Exactly what are her or his deficiencies? How can they be overcome? These questions are answered specifically for each student in the form of an Individualized Education Program required by Public Law 94-142.

Care must be taken to ensure proper placement of visually impaired students in academic science classes. Whatever intellectual requirements are set for nonhandicapped students should also apply to those who have handicaps. Students should not be placed in less challenging classes just because they are different from their classmates. It is easier to modify the curriculum that is on the ability level of the student than to enrich and interest a student in material that is not challenging.

Data-basing your program's modification can be a method of keeping all of your students, handicapped or not, actively involved in planning their courses of study. A student-kept performance chart based on the percentage of correct answers given on a daily quiz can be an ideal way of keeping the student on her or his toes. If the performance chart is kept as a graph, the visually impaired student can use a Swill Stylus and produce a raised line graph of daily quiz grades just as her or his sighted peers can. The student not only would have a visual that the teacher can read in a glance, but also could actually "see" her or his progress. Performance charting by the students works as a motivating mechanism with all types of students of all ability levels. When the graph takes a dip and the student obviously is failing to meet minimum standards, both teacher and student will be able to zero in on the trouble spot and know before it is too late that work is needed on a particular unit or concept.

Precision teaching done in special education classes is very difficult to apply to mainstream science classes. Charting on 6-cycle paper would not be necessary. Regular braille graphs, easily prepared by a secondary-level visually impaired student, should be used. As time passes, the student will become more proficient in keeping her or his own graph, and eventually little assistance will be necessary from the science teacher.

The daily objective quiz can be prerecorded on tape, and the visually impaired student would use earphones to take it with her or his peers during the class period. If a prewritten braille test paper is used, the student can just circle the answers with a pencil, and the quiz can then be easily graded by a non-braille-reading science teacher. Or, as is the case with secondary students, the use of the typewriter eliminates the use of braille altogether.

Science teachers are generally organized and have their course objectives clearly stated. Individual goals for the handicapped student should also be clearly stated. Progress toward these goals should be measured frequently (daily, if possible) and charted by the student.

Consistency in using the program is a necessity. Students begin to challenge each other to do better. This competition among students, handicapped included, is the normalization that will take place when we treat all students in a similar manner.

Whatever information is gathered through this recordkeeping process should be used in making recommendations for change in the student program. The Individualized Education Program modifications can be made from this data. The student, the science teacher, the resource teacher/advisor, and the parents should all be involved in planning this program. It works! Blind students do *see* their progress!

REFERENCES

1. Busse, L.L., and McElroy, A.A. "The Blind Can Chart." *Teaching Exceptional Children*, Summer 1975.

2. Deno, S.L., and Mirkin, P.K. *Data Based Program Modification: A Manual.* Minneapolis: University of Minnesota, 1977.

3. Illinois Office of Education. *Rules and Regulations to Govern the Administration and Operation of Special Education.* Springfield, Ill.: the Office, 1976.

4. Illinois Office of Education, State Board of Education. *State Board of Education Goals Statement.* Springfield, Ill.: the Office, 1975.

5. Niederer, M., and Reguly, B. "A Program To Enable Visually Impaired Students in Illinois To Realize Their Full Potential." *Illinois Libraries* 59(7): 495–497; September 1977.

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12. STRATEGIES FOR STIMULATING SCIENTIFIC INQUIRY FOR ALL STUDENTS

by Paul W. Welliver

An examination of a set of four components and six strategies found in Investigative Science in Elementary Education *that contributes to a successful science program for handicapped and nonhandicapped students. Paul W. Welliver is Professor of Education, Pennsylvania State University, University Park.*

While early science instruction may be desirable for normal children, it seems almost imperative for the development of language and logic in handicapped children. To begin will not be easy, but that matters little: it is in the nature of beginnings that they are difficult. It is time to begin.... (3)

"Oh, Ms. Williams, this is so exciting!"

Carole Williams looked down and caressed the child who had run across the room and thrown his arms around her as she had entered the classroom. She then looked up at the child's teacher. As their eyes met, they both smiled and exchanged understanding nods. Vince was experiencing a rare moment of success and accomplishment!

Only three years before, Carole Williams had been a kindergarten teacher in that same Philadelphia inner-city school. Virtually all of the children in her class were from economically disadvantaged families. It seemed to her that the proportion of handicapped children was unusually high that year. Vince was one of them. He just didn't seem to understand much of what she was trying to teach him. He was quiet and withdrawn. He seldom responded to what went on around him. He rarely attempted to communicate with anyone. He just sat there day after day.

Ms. Williams was a conscientious and dedicated teacher. She was trying so hard to prepare these children to learn the basic skills that she felt were so important to a satisfying, successful life. She felt the despair and frustration of not seeing normal, developmental progress taking place.

One day she had the opportunity to observe a demonstration lesson in process-, inquiry-oriented science being taught to a group of elementary school children. All of the children, representing a wide range of abilities and aptitudes, became involved in investigative activities with simple, commonly available materials. From the involvement and excitement that she witnessed, Carole Williams became convinced that science instruction would perform a valuable function in her curricular program.

However, this conviction led to further conflict and uncertainty. As much as she wanted to provide her students with experiences of the type that she saw in the science demonstration lesson, she was concerned about her own inadequacies in this area. After all, she mused, she knew virtually nothing about science and how it should be taught. Of even greater concern was how she could attempt to introduce science to children with such a diversity of backgrounds, abilities, and physical and mental limitations as she encountered in her classroom.

It was a fortuitous chain of events that led Carole Williams to discover during the following summer that it was, indeed, possible for her to introduce science into her classroom. It came during a brief encounter with some science instructional materials developed for the elementary schools of Pennsylvania.(1) As she saw the critical elements fall into place, her eyes widened and she exclaimed, "*I* can do *that*!"

The science instructional program that she encountered was not much different from many other process-, inquiry-oriented programs available throughout the country. However, it was comprised of a particular combination of elements that she recognized as being useful and that subsequently led to her success in the classroom. Four of these program components are of particular significance.

1. Emphasis on Inquiry and Process

Because the science lessons and related activities are inquiry- and process-oriented, strong emphasis is placed on individual and small-group learning. This situation adapts well to a class with a wide range of abilities. Each child can investigate and explore a particular question, problem, or scientific phenomenon to the extent of his or her level of understanding, ability, and sophistication. Considerable flexibility is provided which allows for appropriate progress of all students, regardless of mental and physical ability.

In some instances, children pursue the lesson individually. In other situations, children of similar ability work together in a common scientific exploration. In still other instances, a less homogeneous group will find it beneficial to pool their talents as a means of accomplishing their goals.

2. Use of Simple Materials

Another factor that contributes to adapting science instruction to a widely heterogeneous group of children is the use of simple, familiar, easily obtainable materials for conducting the science investigations. Paper towels, tin cans, wax paper, cardboard, paper cups, and soda straws are typical of the apparatus used to conduct experiments and carry out observations.

As a result, the children are not intimidated by the equipment they are to use. No unfamiliar apparatus has to be mastered. Furthermore, no concerns exist over damage of equipment or personal injury. Some children who, due to the nature of their handicaps, may have had problems in utilizing more traditional apparatus can safely pursue their investigations utilizing these simple items. At the same time, appropriate and significant investigations can be undertaken.

3. De-emphasis of Science Content

Concurrent with the instructional emphasis on inquiry and process is a de-emphasis of science content. This orientation avoids the situation in which a slow learner is overwhelmed by a large body of information that must be mastered in order to achieve a feeling of success.

Although this feature enhances science instruction for children who may have difficulty with the mastery of an extensive body of science content, it in no way inhibits learning on the part of students who are inclined to pursue more scientific facts and information. It is a widely held misconception that *inquiry science* and *content science* are somehow mutually exclusive, that these approaches present an either-or choice. Actually, an inquiry approach, if properly managed, can lead to a wealth of content far beyond what might be prescribed by a textbook approach through which a limited amount of content is presented.

An inquiry approach permits and, indeed, encourages the learning of content to a degree that is restricted only by the limits of the individual child to comprehend. This, therefore, is why this de-emphasis of content is so important to classes that include children with a wide range of abilities. Each child can extend learning to the limits of his or her capability without being either threatened or restricted by a prescribed amount of content.

4. Emphasis on Appropriate Instructional Strategies

Assume, therefore, that the teacher is conducting a science instructional program that places a strong emphasis on inquiry and processes, is not limited to a set program of content, and utilizes simple, readily available materials. Such a program cannot be effective if the teacher continues to use the same instructional strategies that are effective in the more traditional curricular approach.

As a result, this fourth element consists of a series of basic instructional strategies that a classroom teacher can use in order to stimulate and facilitate exploration and inquiry on the part of the children. These six strategies are certainly not exclusive and all encompassing.(1) They do, however, provide a foundation upon which others can be added.

Strategy 1. Teacher questions and statements require students to examine and manipulate the materials they are using to arrive at their answers. The teacher using such a strategy requires that the student derive answers from the manipulation and observation of materials. Responses can provide the basis for additional questions for which further experimentation and observation can be developed in order to formulate more answers. As a result, all children can learn and be successful because such success is based on the sophistication of their inquiry and not solely on prior knowledge.

Strategy 2. The teacher fosters students' support of their inferences by leading them to establish a direct relationship between their ideas and the observational evidence on which they are based. Under this instructional strategy, students learn to relate their ideas and inferences to observational evidence. The first strategy is, therefore, taken an additional step by which the student is asked to support ideas by using evidence from observations. Again, basic skills in logic and critical thinking are fostered.

Each child within a class is challenged to the extent of his or her ability and understanding. Furthermore, the child is placed in the position of being self-correcting if previously stated ideas and assumptions are not supported by evidence. This establishes an atmosphere of self-sufficiency and worth within the child when he or she can support the accuracy and correctness of ideas rather than relying on the teacher for final judgment.

Strategy 3. Student interpretations are considered acceptable (even though they are partial or temporary conclusions) as long as the evidence from their investigations and experiences supports their responses. Obviously, this strategy teaches an important scientific principle. All explanations, including those of trained scientists, are tentative and subject to change as new evidence is acquired. So, too, must the teacher accept ideas and interpretations as long as available evidence supports them. However, of greater importance is the effect on the student. Nothing can be more devastating to the confi-

dence and initiative of some children than being told that they are wrong when all of the evidence available points to their being correct.

In order to encourage desirable free investigation, the teacher accepts such ideas but then asks questions that will lead to additional activities, new data, and, possibly, revised ideas and interpretations.

Strategy 4. Reasonable time is provided during discussion for observation, thought, and reflection. Based on the research of Mary Budd Rowe (12), this "wait-time" permits children to think through their observations and other available information and to formulate more valid responses. Rowe has also found that when such time is provided following a question, children tend to give longer responses and answer in complete sentences. Students are then able to derive ideas from their experiences rather than relying on stock, memorized answers which may have only limited meaning to them.

As a result, the social climate of the classroom is prone to change from a teacher-centered orientation to a child-centered focus in which children of varying ability can feel more comfortable and secure.

Strategy 5. Teacher questions and behaviors emphasize the use of processes including observing, classifying, communicating, measuring, inferring, predicting, and experimenting. These process skills are, of course, basic to inquiry science. Furthermore, they are important to all other curriculum areas and, indeed, are essential life-coping skills. Practice in systematically utilizing these skills makes children less dependent on specific information and better able to deal effectively with new problems and situations.

Strategy 6. Teacher questions and statements encourage wider student thought and suggestions for additional investigative behavior. Through such a strategy, the teacher creates an open-ended environment in which children identify new directions and questions to explore. Again, each child is able to flourish in such a situation to the extent that his or her capabilities permit.

It is, therefore, these four elements—(1) emphasis on inquiry and process, (2) use of simple materials, (3) de-emphasis of content, and (4) emphasis on appropriate instructional strategies—that enabled Carole Williams to introduce science instruction into her inner-city kindergarten classroom. Despite her lack of background in science and the wide diversity of physical and intellectual abilities of the children, the enthusiasm for science grew and spread throughout the entire school. Within a year, Ms. Williams was on leave from her kindergarten classroom and traveling throughout the entire school district helping teachers to discover the excitement of her experience.

During this contact with hundreds of elementary school teachers, Carole Williams made an interesting discovery. Because of these key factors in science instruction, she was receiving favorable reports from teachers of many types of students, ranging from classes for the mentally retarded to special classes for the gifted, as well as classes in which children with a wide range of physical and mental capabilities were grouped together.

Then one day she responded to a call from a teacher, in her home school, to whom she had introduced these science instructional materials. She was invited to visit the classroom and see how the children, many of whom she had taught three years before, were reacting to their science experiences. With the invitation had come the hint that she might be interested in seeing if she could observe any changes in Vince!

What she was to experience in her encounter with Vince helped to further confirm the phenomenon that she was now beginning to observe more and more in her work with children and teachers. This was that Benjamin Thompson (4) was correct in his observation that, "Science can become an unsuspected ally in the struggle to provide success for the handicapped children who seldom enjoy success in school."

REFERENCES

1. Alfke, D.; Shrigley, A.; and Welliver, P. *Investigative Science in Elementary Education: ITV Handbook for Teachers.* Pennsylvania Department of Education, 1975.

2. Rowe, M.B. "Science, Silence, and Sanctions." *Science and Children* 6(6): 11-13; March 1969.

3. ——. *Teaching Science as Continuous Inquiry.* New York: McGraw-Hill Book Company, 1978.

4. Thompson, B. "Science for the Handicapped." *Science and Children* 13(6): 5; March 1976.

13. MULTISENSORY SCIENCE EDUCATION—MEETING SPECIAL CHALLENGES

by Larry Malone and Linda De Lucchi

A description of the multisensory materials produced for the visually impaired in the SAVI program. They have found that such a carefully prepared program results in the growth of student self-esteem and confidence. Within the context of the multisensory experience, the students' handicaps are circumvented or "neutralized," resulting in success which produces a "good feeling" that often carries over into other aspects of life. Larry Malone and Linda De Lucchi are Curriculum Developers, Lawrence Hall of Science, University of California, Berkeley.

For more than a decade, the Lawrence Hall of Science (LHS) at the University of California, Berkeley, has been prominent in science curriculum development and implementation. LHS has used a multisensory approach to science teaching from the onset of its involvement in the field. Although reading the educational materials and literature related to the early projects eminating from the Hall will reveal only incidental allusions to a multisensory approach, the history of multisensory science education is recorded in the basic philosophy and program strategy underlying every Hall project.

Lawrence Hall of Science projects feature materials-centered, hands-on student learning experiences. The teacher acts as the educational facilitator and lesson coordinator; the students act as observers, investigators, and interpreters. Every student has science materials right in front of her or him. The experience is personal, and all senses are drawn into service for gathering "scientific information."

The Science Curriculum Improvement Study is the senior citizen of the LHS projects. SCIS is a K-6 life science and physical science program for the regular classroom. At the time of its development the authors emphasized the use of sensory input. If a solid material is most effectively differentiated from a second material by texture, the students are encouraged to "observe" by feeling. Similarly, students use their noses to gather irrefutable evidence that something is dead and decaying. The sound of gas evolving from an experiment and the temperature changes of an endothermic reaction are critical observations that carry the SCIS student far beyond the visual mode of "read and watch."

In the late 1960's SCIS came to the attention of educators of the visually impaired. Here, they recognized, was a program that reached three-quarters of the way to the blind learner. With some modifications to measuring tools, such as thermometers and measuring tapes, and some adaptations of certain activities, such as substituting motors for light bulbs in electrical circuits, blind students could have full access to science learning right alongside their sighted peers. *Access* is the key word here. The methodology and approach utilized in SCIS were ideally suited for teaching visually impaired youngsters; Adapting Science Materials for the Blind was a project directed toward removing the material barriers that prevented visually impaired students from learning.

In 1976, LHS started work on a project to produce science materials specifically designed for the visually handicapped population—Science Activities for the Visually Impaired (SAVI). Lesson plans and hardware were carefully prepared and tested with visually impaired youngsters throughout the country. Historically, visually impaired youngsters were the original "mainstreamed" students, integrated into regular classrooms for decades with success. Consequently, while SAVI materials were being tested with mainstreamed visually impaired students, they were *also* used with a good number of regular learners, and teachers recognized the value of the materials for all of the students in their classes. At the same time we observed a "creep effect" as the SAVI materials found their way into classes with learning disabled, emotionally handicapped, mentally retarded, orthopedically handicapped, and multihandicapped learners. The response was unanimously positive—multisensory experiences involved everybody. We now clearly stress the multisensory aspects of the SAVI materials and try to build versatility into each activity in order to reach as many learners as possible.

As the project materials become more flexible and versatile, the product is evolving into something that is more than a science program—it is becoming an instructional medium. Through the medium of science activities, youngsters can apply the skills they are learning in language and computation. Handicapped youngsters, often deprived of opportunities to acquire fundamental skills for independent living (using a knife, pouring, measuring,

maintaining living organisms, etc.), gain experience manipulating new objects. And the less tangible learning areas, such as social development and self-esteem, are exercised as youngsters take part in science in investigations with their peers.

Science taught using the multisensory approach is motivating. Students, handicapped and otherwise, get involved and apply themselves not only to the science content, but also to the language and computation skills incorporated in each activity. Multisensory materials permit students to use alternate senses to make observations, thus successfully circumventing their handicaps. The special student is *fully able* in the context of science.

Success becomes an issue where learning disabled students, specifically language disabled students, are concerned. The argument has been lodged (and with good reason) that we should capitalize on the motivational qualities of hands-on science to stimulate reading and writing skills. The other side of the argument is that we must circumvent the reading and writing deficits in order to provide successful learning experiences. The latter is more in keeping with the goals of multisensory science experiences—providing pathways to achieve successes by circumventing handicaps. But the former is certainly justifiable and worthy of exploration.

A multisensory science activity has four principal goals for the student: (1) to increase the understanding of science content; (2) to develop science process skills; (3) to strengthen manipulative skills; and (4) to apply fundamental academic skills (language and computation) within the context of science. We'd like to expand on each of these goal areas to expose some of the special considerations that go into the preparation of a multisensory lesson plan that would ensure access to learning for every youngster, and then to amplify this discussion with examples in both life science and physical science.

CONTENT ACCESSIBILITY

One primary goal of a science program is to teach science—the content of science. A basic comprehension of the workings and structure of our universe is an important part of every person's education. The first challenge facing those who prepare multisensory materials is to ensure that all learners are presented concepts in a way that is comprehensible in terms of their experience and their developmental level. This necessitates providing student materials that satisfy the needs of all: blind, deaf, learning disabled, and orthopedically disabled. We devote our attention to macroscopic investigations—nothing microscopic. Experiences are concrete rather than theoretical. Investigations are engineered so that youngsters actually find something out rather than being told what should be happening. Concepts are developed through experience.

Consider germination. We want to teach the concept that seeds germinate, and that there are similarities and differences in the way different seeds germinate. The first step is to get several different kinds of germinated seeds in front of the students to observe. For blind youngsters it is important to provide large, *complete* seedlings that clearly exhibit roots, shoots, cotyledons, and seed coats. Different seeds have unique odors as they germinate. Students can use these odors as differentiating properties. The concept of germination (the content of the activity) is distilled from the *experience* of "observing" a number of examples of germinated seeds.

Another concept dealt with in a science activity is the acidity of foods. We want students to know that certain foods have acid in them, and that baking soda can be used as an indicator to verify the presence of acid. In order for all learners to observe evidence of the presence of acid, the activity must be engineered so that the reaction is not only seen, but also heard, and so that the volume of resultant gas is felt. To accomplish this, the acid/soda reaction is performed in a closed bottle into which a syringe is inserted. Students can see and hear the reaction, and feel the syringe plunger being pushed up as a result of gas evolution. The concept of food acid results from the multisensory experience of acid and soda in a specialized apparatus.

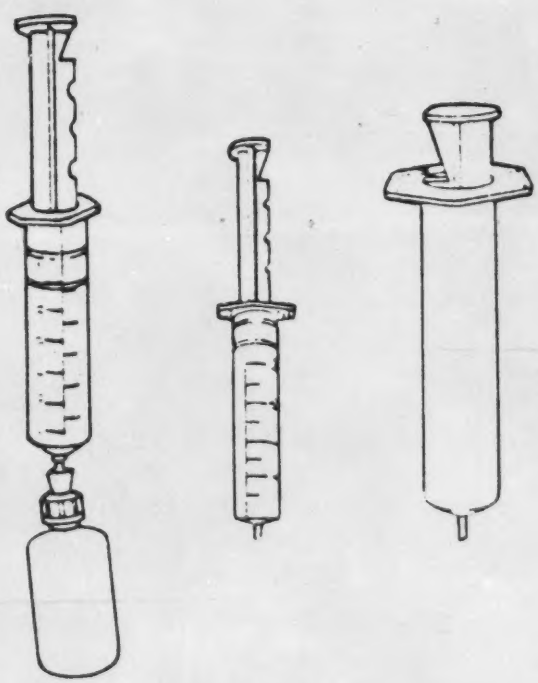

Figure 1

PROCESS ACCESSIBILITY

The processes, or actions, that permit students to make discoveries and arrive at understandings are equally important goals of a science activity. Again, careful attention to the details that permit all students to conduct experiments, measure materials, and make observations will help them become independent investigators and logical thinkers. So the second challenge to multisensory activity writers is to design techniques and tools that are understandable by the youngsters and provide them with avenues for independent investigation.

To ensure that all students have full access to the concepts of science, we avoid sophisticated "black box" tools and resist doing things *for the students* that might result in a gap in their understanding of the process of investigation. The learners must take an active role in every part of an activity in order to be able to integrate the parts into a consistent whole.

Germination is more than a seed that has opened and exhibits roots and shoots. To fully understand the process of germination, youngsters must start with seeds, do something to them to cause change, and then observe the developmental changes that occur over time. The process can't take too long or the students will become bored, so the seeds chosen must develop in a week or so. And the process must be simple enough for the students to initiate all of the procedures so that they can attribute outcomes to their actions.

Generations of students have put seeds in moist cotton or paper and observed changes. These are not appropriate techniques for blind and orthopedically handicapped students; germinating seeds are injured as the observers try to disentangle them from the medium, and they are impossible to return to the growing chamber. For all youngsters to observe germination, a commercial seed sprouter in several layers is the answer. Seeds are easily irrigated daily, and easily removed, observed, and returned at any stage of development any number of times. Such an apparatus provides all students with access to the process of germination, the changes that occur, the time it takes, and the environmental conditions that promote germination (Figure 2).

Knowledge of acid in foods is interesting, but perhaps even more important is knowing a process for determining if a food has acid in it, and if so, how much. Using the bottle and syringe mentioned above gives all learners access to a process for making these determinations. Also, the valuable skills of controlling variables and sequencing operations come into play as the process is developed.

Students put one spoonful (1 ml) of baking soda in the bottle and screw the lid on tightly. They then take up 5 ml of vinegar with the syringe, and poke the syringe tip into the hole in the cork. The vinegar (acid) is squirted

Figure 2

into the bottle, and the resulting reaction pushes the plunger upward. Blind youngsters can feel it happen. When acids *in foods* (citrus juices) are tested in this manner, their strengths can be compared to the strength of vinegar (a standard) by comparing how far the plunger is pushed up. Converting a traditional classroom reaction into an investigative process adds richness to the science program for all learners.

ACCESS TO MANIPULATION

If students learn best by doing their own investigating, it is essential that the tools and objects that they must manipulate be appropriate to the needs of the students. The third challenge to the educator preparing multisensory science materials is to ensure that the size and complexity of the science materials and recording tools are appropriate for the coordination and strength of the students. Manipulations should be challenging, but not difficult or tedious to the point of frustration. The daily life applications of well-developed manipulative skills are obvious, and a well-planned multisensory science program includes a great deal of manipulation.

The germination activity is an example of just such a set of manipulations. Youngsters can take total responsibility for the experiment. Seeds used in the activity—beans, peas, sunflowers, and pumpkins—are large. The seed germination trays nest and are designed in such a way that the youngsters need only to measure 1/2 liter of water and pour it into the top tray. The water automatically flows through all layers, irrigating all of the seeds. Roots, seed coats, shoots, cotyledons, and swelling are easily observed as sprouts are not tangled in cotton or

covered with soil. The youngsters can handle the operations independently.

The activity of testing food for acid involves many operations. The students measure baking soda with measuring spoons and liquids with a syringe. They pour, screw lids on bottles, use a knife to cut fruit, squeeze juice into a cup, and record data. The modified syringe and reaction bottle allow all students to perform these manipulations and to arrive at the same generalizations based on independently collected data.

ACCESS TO OTHER DISCIPLINES

The current trend in education is to fortify every youngster's intellectual armory with a solid bank of fundamental academic skills. To be sure, the basic skills of language and computation are essential for the academic survival of all students. However, practice and drill can develop proficiency to only a degree; to be competent with these skills, the student must be able to *apply* these skills to real learning and living situations. Hands-on science is just such an application situation. The fourth challenge to the educator preparing multisensory science activities is to amplify the opportunities inherent in most lessons for exercising these skills. In this way the teacher can take full advantage of the motivational aspects of science to incorporate application experiences from other disciplines into the multisensory science lesson.

Seeds undergo radical changes during germination. We encourage the development of descriptive, verbal language to express the changes observed. The new structures that emerge in germinating seeds are named, thus increasing the student's vocabulary. Students read categorical labels and sort sprouts according to whether or not they exhibit various characteristics. A "summary report" might be written by the students to capsulize what was learned about germination.

When students investigate the acid in foods, they judge the acid content of a specific fruit juice by observing the amount of gas liberated in the reaction. The acid "standard," vinegar, yields a full syringe of gas. An acid that yields half as much gas is "half as strong" as vinegar. This activity gives the youngsters an opportunity to develop and/or apply their understanding of fractions and proportionality. The students are also given the opportunity to "double the amount," or "use twice as much" of one of the reactants to see what will happen. These fundamental concepts of computation are often more easily developed in a situation such as this where concrete objects and observable outcomes are used to develop abstract ideas. Multisensory experiences with concrete phenomena permit all learners to share in the first-hand observations that assist concept development.

The Sprouting Seed and *The Acid Test*, the activities highlighted above, are two of the 48 activities developed by the SAVI project. All 48 address the four challenges posed here, and it has been the experience of many of our users that the SAVI activities answer those challenges.

In closing, we'd like to touch lightly on a fifth challenge that is the responsibility of every educator in every specialty at every level—to help develop a complete human being in the person of every student she or he touches. In the case of the handicapped youngster, the challenge must be met with extra determination. We're not going to suggest that a multisensory science program is the instant answer to the total integration of the handicapped youngster into all aspects of life, but we will say that the growth in self-esteem and confidence seen as a result of a carefully prepared science program is undeniable. At least within the context of the multisensory experience, the student's handicap is circumvented or "neutralized." The resulting success produces a good feeling, and the good feeling often carries over into other aspects of life.

14. USING SCIENCE TO STRENGTHEN COMMUNICATION SKILLS OF HEARING IMPAIRED STUDENTS

by Donald C. Orlich and Kathleen M. R. Black

This chapter describes a program using SCIS materials with hearing impaired students to strengthen both their science and their communication skills. Donald C. Orlich is Professor of Education and Science Instruction, Washington State University, Pullman; and Kathleen M. R. Black is a teacher of the hearing impaired, Lincoln Middle School, Pullman.

One area of American education that is gaining momentum is the adaptation of instructional materials and curriculums for handicapped children. The major impetus for these widespread efforts in science education for the handicapped stems from Public Law 94-142, the Education for All Handicapped Children Act of 1975. Much has been written about PL 94-142, and it must be noted that one aspect of the law has been to make available the totality of the curriculum to all handicapped children. In 1978, the National Science Teachers Association (NSTA) conducted a conference under the auspices of a National Science Foundation grant concerning science education for handicapped children. The outcome of the conference was the 1979 NSTA publication *Sourcebook: Science Education and the Physically Handicapped.* (2) The *Sourcebook* provides excellent background information concerning science education for most handicapped students. However, in the area concerning the hearing impaired, the *Sourcebook* provides only general strategies for science education and the application of science teaching to other content areas. Thus, there is a need for detailed accounts of successful classroom experiences.

The project on which we are reporting took place during the academic year 1978-79 in the Pullman, Washington, public schools. During that academic year, the National Science Foundation's Pre-College Teacher Development Program funded a one-year project to help extend the science knowledge of elementary teachers in the Pullman school district through a grant to Washington State University (Grant No. 78-03954) with the U.S. Office of Education. Co-author Orlich directed the project with the assistance of Dr. James M. Migaki, a science educator; Dr. George Williams, an ecologist; and Dr. Gerald Tripard, a physicist. As an integral part of the project, Science Curriculum Improvement Study (SCIS) was instituted in the special education classrooms of the district.

Kathleen M. R. Black, co-author of this article, became intrigued with the possibility of using the *Material Objects* component from SCIS in her self-contained class for the hearing impaired at Lincoln Middle School.

THE SCIS RATIONALE

SCIS is a concept- and activity-oriented elementary school science program which has both physical and biological science components. The program is designed to be used throughout the year at each grade level, kindergarten through grade six. A definite cycle of three stages is suggested in the teaching of SCIS. In the initial *exploration* stage, activities are organized and the children learn through spontaneous interactions with the various materials. The second stage, *invention*, appears when the teacher labels the concept being studied. The labeling of the concept comes *only* after the children have had concrete experiences that illustrate the respective specific concepts. The last stage in the SCIS developmental cycle is called *discovery*. It is during the discovery phase that children learn to make new applications of the concept or skill that has been learned.

The SCIS curriculum is based largely on the theories of Jean Piaget. In Piaget's theory, mental processes are suggested to take place through a series of operations. There are three major stages within Piaget's theory: (1) pre-operational, (2) concrete, and (3) formal operations. In the SCIS program, the emphasis is on the concrete operational stage—that is, using materials and objects to learn scientific phenomena. To be certain, logic and reasoning are also developed as a part of that stage.

TEACHING THE HEARING IMPAIRED

The ability to communicate effectively is one of the major goals of teaching hearing impaired children. *Com-*

munication is one of the thirteen major scientific processes that were defined l y the American Association for the Advancement of Science in its classic curriculum funded by the National Science Foundation and entitled Science—A Process Approach (SAPA). Thus, while expanding scientific literacy is a major goal when teaching SCIS, it became apparent to the writers that there might be a link between teaching science processes to hearing impaired students and helping them to communicate more effectively.

Humans have developed a compendium of symbols and patterns for expressing experiences, philosophies, and emotions. These linguistic symbols and patterns are acquired and used primarily through the auditory channel. Any interferences with the auditory channel of communication causes experiential deficiencies, and, as a result, language structure is not acquired in a "normal pattern." Thus, children in hearing impaired classes must be provided with a rich spectrum of *experiences* that will help them to acquire and internalize language so that their auditory deficiencies are minimized and their concrete and formal operational experiences maximized.

The teaching of language to hearing impaired students at Lincoln Middle School is provided through the use of *Total Communication*. The teaching philosophy of Total Communication combines finger spelling and Manual English (a sign language system) with the spoken word, and emphasizes the use of residual hearing and the visual modality of lip reading. The teaching of language is an integral part of every activity in the classroom. One might summarize the teaching of hearing impaired students by stating that their curriculum is in fact "language arts." All educational experiences are integrated so that language arts instruction is the top priority.

With the adoption of SCIS in the classroom, the teacher (Black) was faced with the task of providing adequate scientific literacy experiences to the children. *Material Objects*, the first level of the physical science sequence of SCIS, appeared to be a logical beginning point to apply science in conjunction with the structural language curriculum of the classroom. The language program (1) was patterned after a program of linguistic expansion through reinforced experiences and continuous evaluation. The program provided a sequential and spiraling curriculum which incorporates five basic steps in teaching language: (1) *comprehension*—developing vocabulary, concepts, and the form of structure; (2) *manipulation*—physically manipulating words and phrases to aid in understanding structure; (3) *substitution*—varying structural elements; (4) *production*—saying and signing simultaneously; and (5) *transformation*—rearranging simple sentence patterns.

It became readily apparent that the five language arts program steps coincided with the developmental cycle of SCIS: exploration, invention, and discovery. SCIS was implemented as an effort to improve the scientific literacy of the children, but concomitantly the science experiences became an extension of the language arts program. (See Table 1 for the relationship of language arts and the SCIS teaching cycle.)

Table 1. Relationship of the Classroom Language Program and the SCIS Teaching Cycle

Classroom Language Program Steps	SCIS Teaching Cycle		
	Exploration	Invention	Discovery
Comprehension		X	X
Manipulation	X		X
Substitution		X	X
Production	X	X	
Transformation			X

The following are examples of the actual implementation of the science curriculum.

Exploration Stage

All instructional objects and materials were presented and manipulated by the students. Later, students participated in "object hunts" around the school grounds, at home, and in the classroom. A variety of sorting exercises took place with objects found on the hunts, with classroom objects, and with materials provided by the SCIS kit. Students explored the materials with a minimum of teacher direction and thus learned about the materials and their properties through their handling of the objects and experimenting with them.

Invention Stage

Students were introduced to the word *object* when referring to any piece of matter. The students were taught a new *sign* (representing a word or concept and illustrated by a specific hand shape, movement, and placement) for the term *object* and shown that this sign had the same placement and movement as the sign for the word *thing* but with a different hand shape. The word *property* was used to refer to any characteristic of that piece of matter or object. As the students were prompted to talk about the objects—"Tell me about the pencil" or, "What kind of material is the pencil made of?"—they would describe the object, its uses, and its properties. Gradually they were taught to identify and describe objects by their properties rather than by their uses.

The term *property* was fingerspelled as there was no available sign to represent the concept. Convergent questions were asked to gain feedback about the students' understanding or recall of a certain fact. For example: "What are the properties of this ball?" A student might reply, "Red and round." The teacher would then reinforce and expand the response with, "Red and round are prop-

erties of this ball." The teacher helped the students to express new concepts by learning new terms, new signs, and new definitions. This strategy enabled the students to interpret their observations and explorations.

Discovery Stage

A chart entitled "Properties of Objects" was designed so that objects could be classified by selected properties. As the students' "property" repertoire developed, more classifications were added to the chart. The chart was always prominently displayed in full view of the class. Initially, the teacher presented the basic classifications. The students were consistently encouraged to add to the list or to illustrate a new use of a property. As the year progressed, the students began to add to the list. These additions were not limited to "science time." The students demonstrated true "discovery" by adding the terms spontaneously in all their classes. By the end of the semester, each student was able to categorize objects by the following properties: size, color, shape, material, and texture. Additionally, they could make comparisons between materials and properties, describe objects, and establish categories. These were all accomplished through both written and verbal expression.

THE ROLE OF QUESTIONING

In teaching SCIS, or any activity-oriented science program, there is the need for the teacher to ask questions appropriate to the concept being taught. In those cases where closure is needed, a teacher asks *convergent* questions. When a wider spectrum of responses is desired, the teacher asks *divergent* questions. Hearing impaired children, however, frequently have difficulties in both understanding and responding to questions.

It became apparent that convergent questions about the science activities were rather easily processed by the children. This was to be expected as most of the language activities of the class were focused on literal processing.

When the teacher began to use more divergent questions—such as, "What happened?" or, "Why?"—the initial student response was minimal. However, through continual use of the more interpretive and evaluative question types, the students began to respond appropriately. Their responses showed growth in both the qualitative and the quantitative components. These responses were reinforcing the objectives that the teacher had established for the structured and nonstructured language program. Throughout, the teacher guided and encouraged the students to "discover" or discern new applications for the previously learned science concepts.

ARTICULATING SCIENCE AND LANGUAGE SKILLS

The *initial* structure of the language program—*Noun*$_1$+Verb (be) + *Adjective* (e.g., ball is red)—was found to be crucial for the students' ability to progress to more complex structures. However, some of the children were experiencing difficulty with the categorization of nouns vs. adjectives. In addition, the appropriateness of the choices of adjectives was often in question. Although the rules of English grammar provide that nouns are "persons, places, or things" and that adjectives are "words that tell about nouns," the basic distinctions were not being fully grasped by the students.

SCIS provided practical, concrete experience for reinforcing adjective and noun concepts. During "language time," emphasis was on further classification and description of nouns and objects by their adjectives or properties.

A FEW SELECTED FINDINGS

Each child was evaluated individually through a daily data-keeping system.

Two children were able to construct a simple sentence of the *Pronoun + Verb (be) + Adjective + Noun* type, through both verbal and written sentence construction with 80-100% accuracy.

A third child was able to construct a simple sentence of the *Noun*$_1$ *+ Verb (be) + Adjective* type, through verbal sentence construction with 40-90% accuracy depending on his or her attentiveness and maturation.

At the end of the 1977-78 school year, students were given the Standard Achievement Test normed for the hearing impaired prior to the inclusion of the SCIS curriculum. At the completion of the 1978-79 year, following the implementation of the SCIS curriculum in the classroom, the tests were repeated. Scores indicated that the students increased on the average of .4 grade levels on the Science Subtest during the 1978-79 academic year. The scores can now become base lines for future reference points of academic growth.

CONCLUSION

Unlike the study reported by Linn and others (3), in which her group compared the relative achievements of

mainstreamed, hearing impaired children against "normal" children and in which cognitive tests showed no significant differences, our methodology tends to *approach* that of single subject design. Our goal was to determine effective ways to integrate science instruction with language arts.

The reader may ask, "Why are they overemphasizing this component?" *Our primary reason is that science instruction in the elementary grades is slowly being forced into the realm of an extracurricular activity and is not being considered as one of the "basics."* This erosion of science is witnessed in states such as Washington where accountability laws all but ignore the teaching of science as a basic subject in elementary grades.

By illustrating that science is, in fact, a major contributor to language arts, there is an opportunity empirically to convince administrators and special educators that science has a place in the ongoing curriculum of handicapped children. It only takes materials, a willing teacher, and a lot of work.

REFERENCES

1. Caniglia, Janis, and others. *Apple Tree: A Patterned Program of Linguistic Expansion Through Reinforced Experience and Evaluations.* Lake Oswego, Oregon: Dormac, Inc., 1972.

2. Hofman, Helenmarie H., and Ricker, Kenneth S., editors. *Sourcebook: Science Education and the Physically Handicapped.* Washington, D.C.: National Science Teachers Association, 1979.

3. Linn, Marcia C., and others. "Science Education for the Deaf: Comparison of Ideal Resource and Mainstream Settings." *Journal of Research in Science Teaching* 16 (4): 305-316; 1979.

4. McGlathery, Glenn. "Analyzing the Questioning Behaviors of Science Teachers." *Volume I: What Research Says to the Science Teacher.* (Edited by Mary Budd Rowe.) Washington, D.C.: National Science Teachers Association, 1978. pp. 13-30.

5. *Material Objects.* Teachers Guide; Science Curriculum Improvement Study. Chicago: Rand McNally & Company, 1970.

15. SCIENCE FOR THE DEVELOPMENTALLY DISABLED

by Judith J. Trotta

The author examines a variety of materials that may be used with the developmentally handicapped child including SCIS, Me Now, *and* Me and My Environment. *The author finds that to survive in the real world, all children must become scientifically literate, and that this concept applies especially to the handicapped if the gap which already exists developmentally between them and nonhandicapped children is not to be allowed to widen. Judith J. Trotta is Coordinator of Special Education, Ramsey (New Jersey) Board of Education.*

Public Law 94-142 is in effect. Under this law a handicapped person is entitled to an appropriate education, an individualized program of instruction, and the least restrictive environment. Much of the controversy today focuses on the phrase "least restrictive environment" and thus encourages the adaptation of existing science programs to meet the needs of handicapped persons in the regular classroom.

In most scientific circles the term *handicapped* is restricted to the physically handicapped (auditorily, visually, or orthopedically handicapped). Even the National Science Teachers Association's publication, *A Working Conference on Science Education for Handicapped Students* (4), deals solely with science education for the *physically* handicapped. This restriction of the term *handicapped* ignores those 1,507,000 persons in this country who are developmentally handicapped (mentally handicapped, if you wish). These developmentally handicapped persons are also entitled to an appropriate education, individualized instruction, and the least restrictive environment.

An "appropriate education" in this country must include science for all children. We have a highly technical environment. For survival, children need to know and understand themselves and their place in this world. For survival, they must learn to observe, to catalogue, to make judgments, and to draw conclusions about themselves and their world. To function independently in the world today, a person needs "scientific literacy." The media constantly assault us with scientific data and terminology, much of which has become part of ordinary conversation. If the developmentally handicapped child is not taught these concepts and this terminology, the gap that already exists between the nonhandicapped child and the developmentally handicapped child automatically widens.

Ten years ago "science" was never mentioned in textbooks dealing with the developmentally handicapped. Searching through curriculums did, however, reveal activities that might be termed *science*: naming of environmental objects, differentiation of body parts, orientation to weather, and planting of seeds. An informal survey of colleagues who teach the developmentally disabled revealed that all taught some aspect of science, that all taught science in irregular schedules, and that few used formal science programs. One colleague even admitted to teaching science only in the spring. The student response reported, however, was universal: "They love it."

According to the American Association on Mental Deficiency, the developmentally disabled are those of subaverage general intellectual functioning originating during the developmental period and associated with impairment in adaptive behavior. There are, as with any handicap, various levels of mental handicaps, ranging from borderline (1.01-2.00 standard deviations from the norm) to profound (5 or more standard deviations from the norm). Those individuals considered here fall in the mild, moderate, and occasionally severe range (2.01+ standard deviations from the norm).

Those students who are borderline and mildly developmentally disabled (those considered Educably Mentally Retarded in New Jersey) either may be truly mainstreamed in a lower-level regular class or may receive their science instruction from their own teacher. Still another solution at the junior high and high school levels is to have the science teacher present "special" science classes to the developmentally disabled. The teacher of the developmentally disabled should take into account that the developmentally disabled student will learn more slowly, at one-fourth to one-half the rate of chronological peers.

Attention span or lack of it may well be another problem. Lessons must be taught by small and sequential steps. The developmentally disabled student may need to

be led step by step to form the first simple hypothesis and even more slowly to form the first conclusion. Since transfer is frequently a difficulty with these students, experiments must be linked to the students' real world.

Originally I "experimented" with teaching science. My class was composed of developmentally disabled teen-agers of the severe-to-moderate range (those considered Trainably Mentally Retarded in New Jersey). My first equipment was an Ideal Primary Science Kit. Since my college background was in science and those were the days when special education students were isolated in church buildings, I decided to see what my students could learn. We "covered" air, water, light, sound, magnetism, and a bit of electricity in a most elementary fashion. My method was mainly lecture demonstrations with student-helper demonstrators. Sometimes I performed a simple experiment and let each student mimic my procedure. Using the experience chart technique, we wrote very simple stories about our experiments, and I diagrammed the experiments. For example, our unit on air included experiments on the existence of air; its volume, weight, and pressure; what happens when air is heated; and where air is. The concept of "air" was mind-boggling to my students, and the simple experiment of imploding a can was relegated to the realm of magic.

I weekly duplicated our experience chart stories and sent them home, hoping some interchange would occur within the family. The response from both students and their families was overwhelming. Being able to share their science experiments with their siblings inflated the self-concept of each student. Here, at last, was a real "subject" that they had in common with their brothers and sisters. They, too, could say, "We had science today. This is what happened in our experiment."

My initial success in science for my developmentally disabled class led me to further inquiry. In our school system the elementary classes use the Science Curriculum Improvement Study (SCIS) program. With the help of our science department chairperson Charlie Butterfield, the school system purchased the first three levels for our special education classes. Science became part of our daily schedule.

The SCIS program attempts to introduce scientific knowledge through experiences with a wide variety of physical and biological materials. The children observe, investigate, measure, predict—always working from concrete models in front of them. The program stresses the four major scientific concepts of matter, energy, organism, and ecosystem, as well as the process-oriented concepts of property reference frame, system, and model. SCIS is divided into a physical science sequence and a life science sequence, each one having six units or levels. SCIS comes equipped with everything one needs including "send-away-for" live specimens and workbooks.

Our progress was slow, but real. More repetition than is provided for in the manuals was frequently necessary. Adjustments for nonreading students needed to be made. Sometimes we again used the experience chart approach: The students told me what to write about our experiments, and I wrote it on the chalkboard. Those who were able to copied it into their workbooks. Some of the specimens seemed too small to be easily observed. Borrowing some ideas from the Biological Science Curriculum Study (BSCS) curriculum for the blind seemed like a good idea, using frogs instead of daphnia, using genetic corn instead of fruit flies, and using bigger tadpoles. I tried keeping vocabulary as simple as possible, but did not hesitate to use scientific terms. Frequently my students' receptive abilities far exceeded their expressive ones, so I taught vocabulary in the context of the science lesson and reused it for writing and language skills. I still send home vocabulary lists, which are the basis of some home interactions and which bring another kind of positive reinforcement.

SCIS succeeds in putting manipulative material and experiments in front of each child or pair of children, fostering the independence we try to achieve with the developmentally disabled. It does not matter to them that academically the material is at an elementary level while they are in high school. These students must be taught to observe accurately while the teacher consciously resists giving cues of any kind. The developmentally disabled must be *trained to report what is observed* and in what sequence and, from that data, *to speculate or infer*. Observing must be separated from teacher pleasing. Observations can be reduced to pictorial representations or single word responses. Developmentally disabled students must be taught *to draw conclusions*, a skill not usually expected of them. Yet, anyone surviving with minimal independence draws many conclusions. The steps to a conclusion must be small, as concrete as possible, and sequential. The students must be taught to use data and observations to disprove a hypothesis as well as to prove one. The concept that being wrong is part of the scientific process is a big revelation. To persons who have been wrong most of their lives, guessing is a big risk. Developmentally disabled students, more than nonhandicapped students, need to be taught to trust those capabilities of observation and to extract information from those observations.

Even without a systematic program as comprehensive as SCIS, opportunities for science education are readily available. Keeping pets in the classroom is an old ruse, but still a valuable one. Participating in the care of classroom pets provides an opportunity for observation as well as teaching a valuable skill for the developmentally disabled to use in later life. We have had guppies, turtles, tadpoles, mice, guinea pigs, caterpillars, neighborhood dogs and cats, birds, and even sheep and horses. One class we know had a huge iguana. I encourage visits from home

pets. The science department at the high school welcomes our visits to its living specimens. Anything living makes a suitable classroom pet. Simple observations of an animal's appearance lead easily to questions regarding why its teeth are sharp or why its feet are that shape. Discussions of natural habitat and simple classification follow. These discussions can be expanded to research and model ecosystems. If the opportunity for mating an animal occurs, the students are able to watch the entire life cycle. If the death of an animal occurs, students learn to accept death as part of the life process. A daily association with any animal stimulates the curiosity of even the least capable student and sometimes amazingly captures the attention of the withdrawn student.

Plants of all kinds offer another science experience. A developmentally disabled student can and should be taught the names of common vegetables, house plants, and garden plants. After all, a rose is not a daisy; why should it be a daisy for a developmentally disadvantaged person? Naming is the first step toward classification. Seeds can be planted and observed any time of the year, not only in the spring. Seeds other than common vegetables and flowers can be planted and charts kept of germination times. Attention can be focused on seasonal plants. Developmentally disabled students can be led to draw conclusions about plant needs by experimenting with seeds and plants under different conditions of light, heat, and nutrients. One of the advantages of having plants around a room is that students may easily observe different kinds of plant propagation. Learning how to plant, transplant, and prune even simple house plants provides potentially valuable skills for the developmentally disabled.

Bird watching is another activity adaptable to developmentally disabled students. The National Audubon Society publishes a wonderful junior bird watching kit. The developmentally disabled need to be taught to name and differentiate the birds around the school and around their homes. Observing where the birds live, what they eat, and how they obtain their food and listening to their songs can be an exciting experience. It is equally important for the developmentally disabled student to learn how to be a quiet, listening observer and to focus attention on an object as small as most birds.

It is a basic right to know and understand one's own body. This is the right of developmentally disabled persons. They have bodies and feelings just like the rest of humanity. They have the right to know the proper location of their organs, their proper names, and their functions. The knowledge of ordinary bodily processes as a part of living seems basic, but it is often denied to the developmentally disabled.

We now include *Me Now* in our science program. (The same publisher produces *Me and My Environment*, which studies the ecosystem and its interrelationship to the person.) *Me Now* was originally formulated by the Biological Science Curriculum Study under a United States Office of Education grant for educable mentally handicapped students, ages 11-19 (mildly developmentally handicapped). It is a two-year program with four units: Digestion and Circulation; Respiration and Body Wastes; Movement, Support, and Sensory Perception; and Growth and Development. Materials include posters, worksheets, pre- and posttest booklets, chemicals, daylight slides, and wonderful film loops that show the actual fluoroscoped digestion of a piece of food, a beating heart, the fertilization of an egg, etc. An added attraction is Dudley, the human torso, whose stomach churns food and whose heart pumps "blood" through see-through veins and arteries. It takes my students four years to complete the four units, but they know their stomachs are not below the waist and that babies do not grow in stomachs.

A person who does not know her or his own body is afraid. Study of the human body is a natural introduction to the discussion of human sexuality. Other people, including parents, are frequently apprehensive about discussing the changes and processes of their own bodies with the developmentally disabled person who is experiencing these changes and feelings. While biological changes in body appearances are observed and experienced, behavioral and emotional changes must also be discussed. I have received much material and help from my own health department and from other sources. The American Alliance for Health, Physical Education, and Recreation, and the Sex Information and Education Council of the United States publish a small book, *A Resource Guide in Sex Education for the Mentally Retarded*, which is a good beginning and which contains an excellent bibliography. (3) Planned Parenthood of Seattle, Washington, publishes a series of illustrations that are simple and explicit. Sexuality as part of a comprehensive science program seems to be less threatening to parents and the general public. Lessons in sexuality must be short, sequential, and to the point. Frequently, the developmentally disabled person has many misconceptions that must be gently dispelled. Instructions for personal hygiene and self-care must be repetitive and specific.

Any science experiment, whether as part of a formal program or as informal observations, has proved to be a stimulating, shared topic for conversations. This aspect is extremely important to the developmentally disabled since their social development frequently lags behind their chronological age. The closer social behavior can be molded to what is considered acceptable for that chronological age, the more acceptance a developmentally disabled person is assured in this society. Social behavior

includes acceptable conversation topics. Through conversation centered around experiments, the students have a chance to feel that their observations are as important as the teacher's or any other student's. Perhaps for the first time in her or his life, the student feels part of the adult world.

But you say, "Do you really learn?" My answer is a resounding "Yes!" I have been surprised at the extent of my students' recall. My students come back in September and can still describe *metamorphosis*—not only of the fruit fly, but also of the caterpillar we found on the geraniums. They are vitally interested in their own bodies, know that they are in their greatest years of change, and take pride in that. They know that the "apartment" parts of our bodies have names, that we all have them, and that it's all right to talk and wonder about them. On the other hand, yesterday's lesson must frequently be retaught today; one unit may take a month, or even a year. But it's worth it!

REFERENCES

1. Biological Science Curriculum Study. *Me and My Environment*. Northbrook, Ill.: Hubbard Scientific, 1976.
2. _____. *Me Now*. Northbrook, Ill.: Hubbard Scientific, 1976.
3. Joint Committee of the Sex Information and Education Council of the United States and the American Alliance for Health, Physical Education, and Recreation. *A Resource Guide in Sex Education for the Mentally Retarded*. Washington, D.C.: the Joint Committee, 1971.
4. National Science Teachers Association. *A Working Conference on Science Education for Handicapped Students. Proceedings*. (Edited by Helenmarie Hofman.) Washington, D.C.: the Association, 1978.
5. Planned Parenthood of Seattle, Washington. *Sexual Education for Retarded Adults*. Seattle, Washington.
6. Science Curriculum Improvement Study. New York: Rand McNally & Co., 1974.

16. SCIENCE FOR DEAF STUDENTS: CURRICULUM SUGGESTIONS FOR GROUPED AND MAINSTREAMED PROGRAMS

by Joanne B. Stolte and Shirley C. Smith

A review of the special needs of and barriers faced by deaf students, both academically and in careers and career exploration. The areas of language development, projective and imaginative thinking, estimation skills, and inquiry skills are explored, as are the barriers resulting from negative societal expectations for deaf individuals. Joanne B. Stolte is Director, Special Projects Division, Research for Better Schools, Inc., Philadelphia; and Shirley C. Smith is also in the Special Projects Division, Research for Better Schools, Inc., Philadelphia.

Deaf students *do* have some special science education needs that are different, at least in degree, from the science education needs of other students. I would like to discuss these needs and to make a few curriculum suggestions for both grouped and mainstreamed programs. Being specifically interested in science career development of deaf students, I will also discuss some science career development needs of deaf students that have become apparent in the course of my research in this area and describe a program now in development that is designed to meet these needs.

First of all, *deaf students need curriculum materials designed to meet their special language requirements.* Hearing children learn language primarily through the processing of an almost constant barrage of speech sounds. Deprived of this experience, the language acquisition of deaf children is a slow and arduous process. The result is a lag in language development that soon leaves the deaf child several years behind his or her hearing peers. Specifically, G. Walter lists three areas in which most deaf students experience language deficiencies: syntactic, lexicon (or vocabulary), and experiential. (23)

In terms of *syntax*, deaf students may not have absorbed the patterning of English rules of syntax already mastered by other students their own age. For example, word order is crucial to meaning in the English language, but this principle often presents confusion to deaf students. An example of this confusion is presented by Harry G. Lang in a paper on the significant traits of hearing impaired physics students; he reports that these students often confuse the meaning of the sentence, "The force caused the acceleration" with its inverse, "The acceleration caused the force."

Deaf children also experience similar difficulties in *vocabulary development.* More often than not, new words must be consciously learned rather than just "picked up" in casual conversation. Similarly, the deaf student is deprived of much casual reinforcement of new words. Words with multiple meanings often present difficulties to the deaf student who, having learned one meaning of a word, is unaware of the subtleties of that meaning and the existence of other, sometimes drastically different, meanings for the same word. For instance, during the introduction of the states of matter, the deaf student might have difficulty in understanding the distinction between liquid and gas since the word *gas* is already understood as a kind of liquid, gasoline. Similar difficulties arise with regard to idioms and other special word meanings.

Deaf children are also often deficient in terms of *experiential background* because they often miss out on many experiences that make up the normal daily activities of most children. As a result of their deafness, they frequently become socially and experientially isolated, whether they live in segregated facilities or within their own homes.

Teachers of deaf students, therefore, must be sensitive to the effects of this experiential deprivation as well as to any syntactic and vocabulary deficiencies that may be troubling their hearing impaired students. An awareness of such potential difficulties should play a role not only in the presentation of concepts and instructions within the classroom, but also in the preparation and selection of materials.

A second area in which deaf students may need special help is the area of *imaginative and projective thinking.* Traditionally, schooling for the deaf has emphasized language development and, in the content areas, the acquisition of information and vocabulary. Consequently, there is usually little time devoted to imaginative and projective thinking. If there is an emphasis on anything, mastery of basic facts will usually take

precedence over other activities less closely related to "getting by." Therefore, although the areas of imaginative and projective thinking may be difficult for the hearing impaired student, they are essential and, as such, must not be neglected.

A third and closely related area that often presents difficulty for the hearing impaired student is the area of *estimation skills*. Science is often held up to most students as a subject in which they must be exact. There has been an emphasis on right and wrong answers rather than on procedural skills. Whereas this attitude limits most students, it appears to be particularly binding on deaf students who tend, by reason of their total educational experience, to hold to the concrete and to feel more secure with precise information. For these reasons, deaf students often need extra help in the nurturing of their estimation skills.

A fourth area in which deaf students may also need additional help is the *development of inquiry skills*. Deaf students, by virtue of their impairment, do not hear all of the hypothesis testing, deductive and inductive arguments, and other logical analyses that are part of everyday conversation, such as, "I think it's going to rain. The temperature is dropping, the wind is coming up, and it's starting to cloud over in the west." As a result, they often experience a lag in this essential area of cognitive development. Teachers of hearing impaired students must be sensitive to this lag and provide the needed support and instruction in the development of inquiry skills.

Lest there be any misunderstanding at this point, it is important to realize that the areas mentioned above—language development, projective and imaginative thinking, estimation skills, and inquiry skills—are areas in which deaf students frequently experience a growth lag. This in no way implies that all hearing impaired students have all of these problems or that any are incapable of developing these skills.

This very important concept leads to a final special need of deaf students within science education, and that is their need *to receive active encouragement to study and learn more about science*. Negative societal expectations for the deaf individual and their transfer to negative self-image and low-level expectations for future occupational status have played a strong role in the discouragement of scientific study for deaf students.

Because of the emphasis on their disability and the resulting lag in language development, deaf students are usually encouraged to spend time on language study rather than to develop scientific interests and take science courses. Indicative of this condition is the fact that the usual array of science courses does not exist in schools and colleges for the deaf even though, in our increasingly technological society, the need for science education is vital to all students.

To counteract these conditions and to develop a greater interest in science among deaf students, a minimal list of suggestions would include the inclusion of more science examples in other courses and the inclusion of science fiction in reading courses; the provision of more science courses for deaf students; the provision of more trained science teachers within specialized schools and classes for the deaf; and an increased awareness of the science-learning potential of the deaf on the part of teachers, counselors, parents, and all other individuals who contribute to and direct the education of deaf students.

The development of this interest in science and the resulting increased knowledge-base in scientific areas are important not only because they help the deaf individual to better function in our society, but also because they qualify deaf students for future career opportunities in science-related fields. However, in the areas of science career development, once again due not only to the disability of hearing impairment but also to personal and societal expectations, the deaf student has some very special needs. Both research in this area and direct experience in the development and implementation of a science career development program for the deaf reveal specific needs for the deaf student. Five of these major needs are as follows:

1. *Role models of young deaf individuals currently employed in science-related occupations.* When deaf youngsters think of a science career, they usually think of a male scientist with a Ph.D. They say, "Very smart!" "Not me!" Therefore, in order to realize that there are science career possibilities for them, deaf youngsters need role models who are young, of both sexes, and from a variety of cultural backgrounds, and who have had various levels of training. Such role models will serve to improve their self-image and heighten their self-esteem by enabling them to project themselves, as young deaf individuals, into responsible positions in the world of science careers.

2. *Visitations to science employment sites.* Deaf youngsters miss out on a lot of daily, informal conversation that gives hearing youngsters information about work facilities and what it is like to have a job. For instance, deaf students tend to ask such basic questions as, "Where do the workers eat?" and, "Where do they keep their coats?" Therefore, it is especially important to take deaf youngsters on visits to a variety of science work sites to give them a clearer understanding of the world of work and of what people do at their science-related jobs.

3. *An indication of what specific science-related jobs will be available.* Many deaf youngsters are aware of recent news about layoffs of engineers and other science employees; therefore, this knowledge

must be balanced by information as to what specific scientific jobs *are* available and, based on current projections, what jobs will exist in the future. Assistance in this area is particularly important for deaf students since they often have difficulty in conceptualizing the future and the changes that will take place. Furthermore, since they already feel they will have some difficulty getting a job, the specific availability of jobs is of particular interest to them.

4. Awareness of the current accessibility of science preparation beyond high school. Deaf students need to know what science offerings are available at the specialized schools for the deaf. At the same time, they need to become aware of all recent legislation that affects handicapped students and eases their participation in educational programs at schools not especially designed for deaf students. They also need information as to how other deaf students have managed their academic programs (particularly science programs) in these schools. And they need to become aware of the multitude of on-the-job training opportunities available with many employers in science-related areas.

5. A realization that science does offer career opportunities for both women and minorities. The literature does show, especially through the work of Judy Egelston-Dodd (8, 9), that deaf women face a double handicap when approaching science careers. In fact, when asked about going into a science career, a young deaf female most typically replies that she can't go into science because she is a woman (not because she is deaf). This reaction reflects that fact that it is still difficult today for women and minorities, particularly blacks, to enter into a scientific career because societal expectations for them are still negative. Therefore, while we work to create more positive attitudes toward the science career potential of the deaf, we must also create more positive attitudes toward the potential of women and minorities to fill responsible positions within science careers.

These and other science career development needs of deaf students are presently being addressed by materials under development at Research for Better Schools, Inc., under a grant from the Physically Handicapped in Science Program of the National Science Foundation. The curriculum being developed is entitled *Is Science a Possible Career for You?* and it consists of a teacher-/counselor guide and a captioned filmstrip. The materials are designed to provide role models, encourage the exploration of science content, and provide expectations regarding science and possible science career development.

The science career opportunities for the deaf are almost limitless. Deaf individuals can and do fill positions in almost all kinds of science-related occupations. However, the number of deaf individuals currently employed in such jobs is still quite small. Deaf individuals remain a virtually untapped source of talent to fill the multitude of science-related jobs created by our increasingly scientifically and technologically oriented society.

REFERENCES

1. Bollon, B. "Preparing Deaf Youth for Employment." *Journal of Rehabilitation of the Deaf* 9: 11-16; July 1975.

2. Boyd, Eunice, and George, Kenneth D. "The Effects of Science Inquiry on the Abstract Categorization Behavior of Deaf Children." *Journal of Research in Science Teaching* 10: 91-99; 1973.

3. Bybee, R.W. "A Review of Literature of Science for the Deaf." *Science Education* 56: 237-242; 1972.

4. _____, and Hendricks, P.A. "Teaching Science Concepts to Preschool Deaf Children to Aid Language Development." *Science Education* 56: 303-310; July-September 1972.

5. Carney, E. "Deaf People in the World of Work." *National Hearing Aid Journal* 24: 14; 1971.

6. Collea, Francis P. "Science in Sounds." *Science and Children* 13: 34; March 1976.

7. Egelston, Judy C., and Mercaldo, David. "Science Education for the Handicapped: Implementation for the Hearing Impaired." *Science Education* 59: 257-261; April-June 1975.

8. Egelston-Dodd, Judy. "Overcoming Occupational Stereotypes Regarding Sex and Deafness." *American Annals of the Deaf* 120: 489-491; October 1977.

9. _____. "A Philosophy and Paradigm for a Career Education Program for Deaf Learners." (Manuscript accepted for publication in *Journal of Career Education.*)

10. Grant, William D. "A Project to Determine the Feasibility of BSCS's *Me Now* for Hearing-Impaired Students." *American Annals of the Deaf* 120: 63-69; February 1975.

11. Haushalter, Robert, and Rosenberg, Richard. "Breaking Sound Barriers for the Deaf Child." *Science and Children* 14: 33; November/December 1976.

12. Hehir, R. "Integrating Deaf Students for Career Education." *Exceptional Children* 39: 611-617; 1973.

13. Lacey, D.W. "Career Development of the Deaf Student and Worker." *New Thrusts in Education of the Deaf.* Rochester: National Technical Institute of the Deaf, 1973.

14. _____. *A National Survey of Career Development Programs in Residential Schools for the Deaf.* Rochester: National Technical Institute for the Deaf, 1971.

15. Lang, Harry G. "So You Have a Deaf Student: Some Educationally Significant Traits of Hearing-Impaired Physics Students and Implications for Teachers in the Mainstream." Paper presented at the Working Conference on Science Education for Handicapped Students, Washington, D.C., April 1978.

16. Moores, Donald F. *Educating the Deaf.* Boston: Houghton Mifflin Company, 1978.

17. Munson, Harold L., and others. *A Paradigm for*

Career Education: Description of the Creed Model Program for Deaf Learners and Materials for Implementation. Rochester: University of Rochester, 1975.

18. Proscia, Vito, and others. "A Challenge to Teachers from Handicapped Scientists." *Science and Children* 13: 15-16; March 1976.

19. Redden, Martha Ross, and Malcom, Shirley Mahaley. "A Move Toward the Mainstream." *Science and Children* 13: 14; March 1976.

20. Rowe, M.B. "Doing Science with Handicapped Students." *Teaching Science As Continuous Inquiry.* New York: McGraw-Hill Book Company, 1973.

21. _____. "Help Is Denied to Those in Need." *Science and Children* 12: 23-24; March 1975.

22. Schein, Jerome D. "The Deaf Scientist." *Journal of Rehabilitation of the Deaf* 9: 17-21; July 1975.

23. Walter, G. "Performance in English Requires Competence in Syntax and Vocabulary Plus Experience." *Teaching and Learning for Careers* (Teaching Institute Newsletter). Rochester: Rochester Institute of Technology, 1977.

17. SOME THOUGHTS ON TEACHING SCIENCE TO THE MENTALLY HANDICAPPED SECONDARY STUDENT

by Marilynne Mathias and Robert A. Johnson

The authors examine the barriers encountered by mentally handicapped students. The authors provide suggestions for dealing with such problem areas as low reading level, limited language skills, short attention span, and low self-esteem. Among the available techniques they present are the provision of more precise teaching, the use of better questioning techniques, and the adaptation of the instructional program to accommodate individual differences. Marilynne Mathias is Director of Special Education Services, Karns City Area Schools, Karns City, Pennsylvania; and Robert A. Johnson is Professor of Science Education in the Department of Elementary Education, Mansfield State College, Retan Center, Mansfield, Pennsylvania.

Mary has an IQ of 144, reads *War and Peace* for recreation, and wants to be a theoretical physicist. George has an IQ of 68, looks at the pictures in a comic book, and wants to survive until next week. George is mentally handicapped. Prior to the passage of Public Law 94-142, you would not have had George in your class. However, now, both Mary and George are in your science class, and both must be taught as much as you can teach them. As a teacher you must "accept them where they are and take each as far as you can."

In a homogeneously grouped classroom, the problems are comparatively minimal. Since all the students in this situation are near the same intellectual level, the common practice is to teach all of them the same material in the same way. The few exceptions who do not grasp the material can be helped individually during "seatwork time" or after class. A teacher can minimize the effect of obvious differences by making slight changes. If, for example, you have a student with poor eyesight, you move this pupil to a seat near the front. If you have a student with poor hearing, you move this student closer to your speaking position.

Adjusting for the mentally handicapped student is not appreciably different from this. Just as you learned the physical characteristics of your regular students, you must now learn the characteristics of your new students and minimize the effects of their disabilities. Studies have produced lists of characteristics of the mentally handicapped. We would like to examine a few of these characteristics and discuss their implications for teaching science to the mainstreamed mentally handicapped student.

I. MENTALLY HANDICAPPED STUDENTS GENERALLY HAVE A LOW READING LEVEL

That statement is axiomatic. You would expect these students to be poor readers. It is not the fact that they do not read well that is the difficulty, but rather it is the severity of the problem. Many of the mainstreamed students could be classified as functionally illiterate as far as the normal secondary science book is concerned. The multisyllabic science vocabulary is not part of the life experience for these students. Even those who could phonetically pronounce the words have neither the experience nor the sound vocabulary to read and understand. The problem is often compounded by the abstractness of the concept being presented.

It is common in today's classroom to have many students reading two or three years behind grade level. However, the mentally handicapped student may be six or seven years behind in reading ability. Just as you adjusted your classroom techniques to accommodate the hearing or vision impaired students, you must now adjust your teaching to the nonreader.

One simple solution might be to secure alternative reading materials. Most school libraries have several low-reading-level, illustrated books on pertinent subject matter. The simplified vocabulary of these science books could give the student the working vocabulary necessary to better understand class discussions. It's true that these books may not have the depth and breadth that you

normally require, but they may be sufficient for the needs of many students.

Some adjustments for the mentally handicapped student will require more of your time and effort. The poor reader, for example, could require a teacher-made glossary for each unit. Little understanding is gained when this mainstreamed student looks in the textbook glossary and reads that an ohm is "a unit of electrical resistance," or worse that "an ohm is the resistance of a column of mercury at 0°C, exactly 106.3 cm long and weighing 14.4521 grams." A teacher-made glossary could simply state that an ohm is "a number that tells how hard it is for electricity to go through a wire."

Compatible laboratory partners, audio tapes, simplified worksheets, and group discussions also can reduce the stress and increase learning for the poor reader.

An area that is particularly stressful for both teacher and student is evaluation. Many of the mainstreamed students will have difficulty reading the traditional secondary science examination paper. If the evaluation system is based solely on written examinations, these students will most likely fail. Even the matching-type questions with long lists of words and definitions tax the ability of these students. Short lists of matching questions or multiple choice questions will give a better indication of the student's knowledge of science and not just her or his ability to read. Essay questions or problem-solving evaluative devices are also difficult for the slow reader.

Success demonstrated in the daily assignments enhances the mainstreamed student's self-concept. Any increased self-concept, however, can quickly be destroyed by an "F" at the end of the marking period. Normal grading procedures are not appropriate for a student already functioning at the lowest level. Determine what the individual student is capable of learning within each unit and then compare her or his learning to that capability.

Ideally, oral examinations on an individual basis would both eliminate the stress and give a better indication of student understanding. Since this is not always practical, perhaps alternatives could be used. Informal discussion with the mainstreamed student could prove more valuable than written examinations as an indicator of knowledge and understanding; it is also an excellent method of determining areas of weakness and misconception. Perhaps an additional assignment or science-related project would be an acceptable substitute for determining grades. In some instances, such as in a description of the water cycle, a simple diagram may be more informative than a written essay for determining how much the student understands.

Remember that any time reading or writing is required from the mentally handicapped student, that student will have difficulty. Whether it's note taking, test taking, reading from the chalkboard, or reading from the text, the subject matter becomes secondary to the struggle of mastering the language of science.

II. MENTALLY HANDICAPPED STUDENTS HAVE LIMITED LANGUAGE SKILLS

Although the speaking vocabulary may appear to be sufficient for your classroom, some language situations are beyond the capability of the mentally handicapped student. Long, involved verbal directions tend only to bewilder; lengthy, complex sentences to confuse. Writing directions in numbered steps on the chalkboard might save a lot of frustration on the part of both the learner and the teacher. Through discrete questioning, make sure that these students understand a particular assignment or process.

Due to limited experience, both personal and academic, the mainstreamed students are not likely to understand the science vocabulary. In a study of pond life, for example, the regular classroom student can associate terms such as *producers* and *consumers* with experiences in other aspects of life. This is not so with the mainstreamed student. The meanings of these words must be explained prior to a discussion of the pond ecosystem. Other words such as *algae* or *protozoa* which are common to regular students because of other science classes, television programs, or personal experiences are foreign to the student with poor language skills.

These students, for the most part, are experience poor. They do not have a large reservoir of experiences to draw from for new concept development. Even apparently obvious relationships that exist between science concepts and the learners' environment must be pointed out. To these students, the concept of a complete circuit in the classroom does not necessarily apply to a flashlight used in the home. The rust on a nail in a test tube may have no relationship to rusty tools in the garage.

Not only is it necessary to point out relationships for practical applications, but also it is necessary to make science relevant for the learner if she or he is to maintain interest. The boy with a car is more likely to learn about friction in the laboratory if he knows he can apply the principles to increasing the life of his automobile in the parking lot.

Relevancy of the material will facilitate learning, but relevancy alone will not overcome language deficiencies or ensure the learning of abstract concepts. Concrete experiences are necessary. Students should first learn the vocabulary, then use this vocabulary in discussing hands-on experiences. Light refraction and reflection have much

more meaning after the student has had an opportunity to "play" with mirrors and lenses. The knowledge then becomes more meaningful if she or he is told how the new information relates to the glasses she or he is wearing.

III. MENTALLY HANDICAPPED STUDENTS GENERALLY HAVE SHORT ATTENTION SPANS

Actually, the short attention span is more a function of the curriculum than a function of the student. Studies have shown that, when material is presented at the level of ability of the handicapped student, the effects of the short attention span tend to be minimized.

Unfortunately, you cannot teach your class of 30 with the same methods and materials required for the handicapped student. There are, however, some adjustments that can be made. Vary your approach to teaching a particular subject. Even your best students get bored with a constant diet of the same methods. During the class period intermix lectures, demonstrations, questioning, and student activities.

Good questioning techniques tend to hold the attention of gifted and slower students alike. We teachers are often guilty of using poor questioning techniques at all levels. One of our weaknesses is that we allow too little time between the question and the expected answer—less than one second. With your best students, this might be enough. With your average and below average students, more wait time is needed. Give the students time to digest the question, mull over the unfamiliar words, and decide upon a response. Then call upon the student for an answer.

Do not exclude the mainstreamed student from your questioning but rather gear the questions to her or his level of understanding. A question such as, "Explain the role of carbon dioxide in photosynthesis," might better be directed at a more talented student. A question such as, "What is one thing needed for plants to make food?" can be correctly answered by the slower students, thus enhancing their self-concepts, and lengthening their attention spans.

IV. MENTALLY HANDICAPPED STUDENTS GENERALLY HAVE LOW SELF-ESTEEM AND LACK SELF-CONFIDENCE

Many of these students have experienced repeated failure in school due to unrealistic expectations based on their physical sizes and chronological ages, while their mental ages may be advancing at only 1/2 to 3/4 the rate of a normal student. Even her or his interests tend to be more closely linked to those of students with similar mental ages. The results of these expectations are that the students see themselves as failures in the classroom, become frustrated easily, and don't try.

The science classroom affords the teacher an excellent opportunity to reverse this trend. Many of the handicapped students are adept at physical tasks and can excel at laboratory investigations. These students, finally, without reading, can succeed. They can get acceptable results. They can learn through the manipulation of materials. It's true that they might not be able to set up an elaborate experiment to test an hypothesis, but they certainly can both see and interpret the results of simple experiments.

V. MENTALLY HANDICAPPED STUDENTS MUST DEAL WITH CONCRETE MATERIALS RATHER THAN ABSTRACTIONS

Jean Piaget has pointed out that children pass through a series of stages of cognitive development that enables them to deal with increasing degrees of abstractions as they mature. The mainstreamed student most likely will not reach a stage in which she or he can successfully think abstractly. Therefore, lessons for these students must not include mental exercises beyond the capability of each, but rather deal with observations and manipulations of concrete materials.

Let them work with materials rather than ideas. Let them use batteries, bulbs, and wire to make a complete circuit rather than expecting them to understand schematic diagrams. Let them mix sand and gravel in water to see delta-type layering of sediments rather than have them describe the effects of velocity on particles of different sizes. Let them observe the effects of shading on photosynthesis rather than requiring them to construct a graph that will indicate plant growth under varied light conditions.

At the end of their school careers these students may not exceed the levels of comprehension normally expected of early middle school students. Yours may be the last (and the first) science class they will ever take. It is not necessary that they learn concepts that will be built upon in later schooling. Science for them may be a matter of survival or, at the least, an increased awareness of their environments.

VI. MENTALLY HANDICAPPED STUDENTS ARE GENERALLY SLOWER IN DEVELOPING THOSE INTELLECTUAL ABILITIES NECESSARY FOR ACADEMIC ACHIEVEMENT

Whether your classroom requires creativity, memory for visual materials, or conceptual ability, the mainstreamed student is likely to lag behind those students with normal intelligence. The regular student may be able to overcome the effects of a rambling lecture or a poorly organized lesson. This is not so with the mentally handicapped. For them, teaching must be well ordered and precise.

Concepts must be broken into their component subconcepts and their required skills, put into a hierarchy from simplest to most complex, and then taught in a step-by-step progression. You must be sure that the student understands each step before you move on to the next topic. The student cannot understand complete circuits if she or he does not understand the difference between conductors and insulators. A student cannot understand chemical bonding without a working knowledge of atomic structure. Each step must be learned, in order, if the student is to achieve mastery of the desired concept.

Teaching mainstreamed mentally handicapped students is not easy. Good teaching for any student requires thought and work. It will take time. At times it will be frustrating. The rewards, however, make it worthwhile. You may find that the rewards go far beyond success for the mainstreamed student. Most likely, with more precise teaching, better questioning techniques, and adjustments for individual differences, all of your students will benefit.

18. SOME PSYCHOLOGICAL CONSIDERATIONS IN THE EDUCATION OF BLIND STUDENTS

by Elva R. Gough

A discussion of some of the characteristics of and barriers for blind students. Piagetian developmental theory is used to demonstrate the need for concrete operational activities, emphasizing the fact that blind students possess the same intellectual potentials as do sighted students, although this potential reaches maturity at a slower rate. Elva R. Gough is Science Educator and Vision Specialist, Dekalb County School System, Smithville, Tennessee.

I. INTRODUCTION

Though much has been written about the psychological implications of blindness, we have little real knowledge about the way the blind student learns. The primary route for obtaining information appears to be vision; yet, the blind individual gains knowledge and successfully competes in a sighted world without vision. We also have no concrete evidence of the physiological processes involved in learning by the blind. The optical pathways and the visual cortex of the brain are apparently bypassed in some manner. But we have no knowledge about the internal organization of information as it circumvents these pathways. The little we do know about how the blind individual learns is based largely on the observations of noted authorities and on research methods for sighted students that have been adapted (sometimes inappropriately) for use with blind students. This survey of the literature attempts to identify some of the learning problems consequent to blindness. The learning we are concerned with here is primarily in the cognitive domain. The term *blind* refers to the total absence of vision.

II. INFORMATION-INPUT SENSES

The blind individual receives information by way of hearing, touch, odor, temperature, and haptics. The haptic route is a combination of touch and movement through which successive impressions are received and fused into the whole. (22) A common error in teaching blind students is the overreliance on only one information input sense, hearing. The spoken word in and of itself is an abstraction. The word *dog* is a furry, four-legged animal, but *cat, cow*, and *mouse* are also furry, four-legged animals. In the absence of a concrete experience with the thing that is *dog*, there is no internal referent for the concept; hence, the concept becomes abstract in nature.

Concrete experiences in which children manipulate objects visually or manually are required for the development of concepts during the Piagetian concrete operational period. (27, p. 127) Moreover, even after the formal operational stage is attained, everytime we come into contact with a new concept, we revert to the previous intellectual stages of development. We turn it in every direction to visualize every aspect of it and press all its buttons to see what happens. The sighted city dweller often learns the concept *chick* from pictures in a book. The blind student never truly knows the concept *chick* until he feels the soft warmth of its body, the fluffiness of its feathers, the peck of its hard bill, and the roughness of its feet and legs; hears its delightful peeping; and smells its "chickness." Child, adolescent, or adult, the blind individual must be given the opportunity for concrete experiences so that real meaning can be obtained for as many concepts as possible. (5, 12, 13, 17)

III. ABILITY

The intellectual ability of blind students has been intensely studied. In summary, the research indicates that when blind subjects are compared with sighted subjects on various abilities—

1. There are no differences in final intellectual development.
2. They do not differ significantly in
   a. Memory
   b. Numerical ability
   c. Verbal ability
   d. Tactual discrimination
   e. Spatial ability when blindfolded.

3. There are no significant differences in divergent thinking.
4. There are no differences in locus of control.

How then do blind students differ from other students in ability? We find poorer performances by blind students than sighted students on tasks requiring dexterity, analytical ability in problem solving, and transition from global to articulated cognitive styles. On the other hand, blind students display greater analytical ability in perception than do sighted students. It is also important to note that those who became blind early in life seem to develop their verbal ability and dexterity to a greater degree than do those who lost their sight later on.

The educational implications of these conclusions are that—

1. We can expect blind students to eventually attain the same levels of intellectual development as do sighted students, convergently and divergently.
2. Since tactile experience is one of the important information-input senses, a large number of diverse tactile activities should be provided to develop dexterity as well as discrimination and spatial ability to the fullest extent possible.
3. Analytical ability in perception should be enhanced and extended to lead directly to analytical ability in problem solving.
4. More concrete activities should be provided to late-blinded students to help them acquire the verbal ability and manual dexterity they will need for communication and learning success.

Harley notes that visually impaired students are characterized by academic retardation that seems related to underachievement. (12, pp. 426-427)

IV. SOME IMPORTANT DETERRENTS TO LEARNING

Blindness has an isolating effect on the individual due to his or her inability to observe and imitate behavior patterns and thereby add them to his or her repertoire of social and other behaviors. (17) These isolating effects tend to divorce the blind student from the rest of society and may even lead him or her "into a world of unreality and fantasy in which he may find compensation for his real or supposed failures." (17, p. 34) The isolating effects of blindness are caused by three factors:

1. Restriction in the number, range, and variety of concepts.
   a. The sense of touch provides information only when actively used for this purpose, whereas vision supplies information constantly during the waking hours.
2. Restriction in mobility.
   a. Reduced mobility limits the number of opportunities for new experiences and, at the same time, increases the amount of dependency.
   b. Increased dependency leads to frustration which can be followed by resentment.
3. Restriction in the ability to exert environmental control.
   a. Inability to control one's own environment leads to insecurity. (17, pp. 32-33)

The effects of these restrictions are readily understood when one considers the question of how a blind child learns to walk. Of course, blind individuals do learn to walk, but this skill is often delayed and sometimes occurs in the absence of a creeping stage. (7) "The retarded intellectual development of some visually impaired can be the result of inadequate opportunity to explore their environment." (12, p. 426)

The sighted society itself is considered a major deterrent to the development of capable, independent blind individuals. (2, 3, 5) Social taboos against touching and societal attitudes that a blind individual is either stupid or a genius are among some of the restrictive factors discussed by Hector Chevigny and Sydell Braverman. (2) While their discussion of pity and its possible root in fear is certainly worth reading, it is inappropriate here except to note that these authors conclude that being pitied implies some type of inferiority.

Consider the frustrations produced within the blind person who is forced to accept a sighted guide to cross the street or is shouted at because his or her lack of vision is thought to also cause deafness. According to Robert A. Scott, "The disability of blindness is a learned social role." (23, p. 14) The social role of the blind person is learned through—

1. Role playing beliefs gained about blind people.
2. Interacting with sighted people.
3. Interacting with organizations established to help the blind. (23, p. 16)

Thomas D. Cutsforth (5) and Louis S. Cholden (3) also agree that the emotional problems associated with blindness are largely due to social influences from the sighted population.

Probably the greatest educational effect of the emotional problems that arise from interactions with sighted individuals is the damage done to the blind individual's self-concept and independence. In fact, visually handicapped students aged 14 to 20 years have been found to possess negative self-concepts. (19) Although self-concept

and academic achievement are not significantly correlated, we suspect that continual contact with individuals who imply we are inferior, whether it be mentally or physically, leads us to question our own ability. Eventually, we could even internalize this attitude and actually believe we are inferior. With such a self-concept, there is little motivation for learning. Consequently, we put forth only enough effort toward becoming educated to keep from being hasseled as we go through school. Such a student must be provided with learning tasks that have been broken into numerous small steps that will permit attainment of a long series of successes. The attention of the student must be actively directed toward recognizing his or her successes and helped to build a positive self-concept. As the student progresses, he or she should be given more and more responsibility for directing individual learning and for achieving goals that are meaningful to him or her.

B. Lowenfeld (16) and C.J. Davis (6) have identified specific concerns that blind adolescents have: (1) how will they learn about the opposite sex, (2) what symbol can be used for independence to replace that of driving a car, (3) how will they deal with prejudices sighted people have about blind people, (4) will they pass their handicap to their children if they marry, (5) what kind of job can they get to support themselves, and (6) will they be capable of living an independent life? Blind adolescents undergo the same physiological and psychological changes as do sighted adolescents and, like their sighted peers, act out these conflicts in explosive ways. (3) The blind adolescent is *NOT* capable of dealing with his or her blindness until first resolving the problems of being an adolescent. In other words, he or she is an adolescent first and, after that, a blind adolescent. (3, p. 55)

V. ADVENTITIOUS BLINDNESS

Adventitious blindness is the loss of sight at any time after the age of five years. Those individuals who lose their sight prior to the age of five have little or no visual memory and are frequently grouped with congenitally blind youngsters. "... after cancer, blindness is the most dreaded affliction in our population...." (20, p. 528) The following discussion is restricted primarily to adolescence and young adulthood.

With adventitious blindness comes a complete reorganization of the individual. (3) Sensory and motor reorganization is rapidly accomplished after sudden blindness. (5, p. 123) Blindness that occurs gradually is more difficult for the individual to accept, and, in this instance, reorganization may require a protracted period of time. Three stages occur before rehabilitation can truly begin: shock, depression/grief, and anger, which may be concurrent with the depression stage. (4)

VI. BLINDNESS AND PIAGETIAN DEVELOPMENT

The blind child, like the sighted child, passes through all the Piagetian stages of intellectual development, from the sensori-motor stage to the formal stage. There is obviously a variance in the age at which Piaget predicts each stage will develop and the age of actual attainment of the various stages, at least by American children. For example, A.E. Lawson and J.W. Renner (15) assessed the Piagetian developmental levels of 134 sighted high school science students using tasks for conservation of weight and volume, separation of variables, and equilibrium in balance. They found that none of the 50 biology students was fully formal operational, only 4.0 percent of the 51 chemistry students were fully formal operational, and 12.1 percent of the 33 physics students were fully formal operational. Yet Piaget predicts development of the formal operational stage between the ages of 11 and 15 years. (11)

Where does the blind student fit into this picture? Apparently, the blind child and the sighted child began life on an equal basis with babbling beginning about six months of age in both children. (11) Around the age of eight years, the sighted student and the blind student are more or less equal on classification and seriation tasks. (8) Leslie C. Higgins' work in Australia on classification performance by blind and sighted children lends support to this conclusion. (14) Apparently, at least some blind children begin to lag behind their sighted peers soon after the age of eight, depending on several factors such as IQ, amount of vision, and experience with manipulative tasks. (8) Still another factor appears to be the place of residence of the blind student—at home or in a residential school. Blind students living at home were not different from sighted students on tasks of weight conservation in a study by B. Brekke, J.D. Williams, and Perla Tait. (1) Residential blind students lagged behind both these groups.

B. Stephens and K. Simpkins found cognitive lags of about four years in 75 congenitally blind students as compared to 75 sighted students. (26) There were three groups each of sighted and blind students: one group 6 to 10 years of age, one 10 to 14 years, and a third group 14 to 18 years. Nineteen Piagetian tasks of reasoning were administered individually to each student. The deficits identified in the congenitally blind students were even more obvious when mental age and chronological age were controlled. This investigation was followed by the successful development of remediation procedures that

emphasized teaching reasoning process through concrete activities. (25)

In summary, then, although blind students possess the same intellectual potential as sighted students, as noted in Section III, this potential reaches maturity at a slower rate. Again, emphasis is placed on concrete activities: "motoric transformations form a base for cognitive processes long before language comes on the scene." (10, p. 202) Active experiencing, thus, must begin in infancy. According to G. Revesz, "It is characteristic that blind children have to be specifically taught to examine objects accurately by touch." (22, p. 75) So we must teach blind students to use their tactile senses to obtain a wide variety of information which is accurate. "In both child and adult, *perception* is the dominant mental activity." (21, p. 79) The difference between them is that the adult exhibits "mobility within a conceptual structure." (21, p. 79) And, if further encouragement is needed for using concrete learning activities, Beth Stephens reminds us, "Unless visually handicapped children have experienced the concrete world, and have involved their bodies in acting upon it, true concepts elude them." (24, p. 111)

REFERENCES

1. Brekke, B.; Williams, J.D.; and Tait, Perla. "The Acquisition of Conservation of Weight by Visually Impaired Children." *The Journal of Genetic Psychology* 125: 89-97; 1974.

2. Chevigny, Hector, and Braverman, Sydell. *The Adjustment of the Blind.* New Haven, Conn.: Yale University Press, 1950.

3. Cholden, Louis S. *A Psychiatrist Works with Blindness.* New York: American Foundation for the Blind, 1958.

4. Curtin, G.T. "Social and Psychological Implications." Speech given at the Seminar of Methods of Independent Travel for Blind Persons, sponsored by the Committee on the Blind, United Community Services of Metropolitan Boston, Boston, April 4, 1961.

5. Cutsforth, Thomas D. *The Blind in School and Society.* New York: D. Appleton and Company, 1933.

6. Davis, C.J. "Adjustment of the Blind Adolescent." *Blindness Research: The Expanding Frontiers.* (Edited by M. Goldberg.) University Park: The Pennsylvania State University Press, 1969.

7. Fraiberg, S. "Parallel and Divergent Patterns in Blind and Sighted Infants." *Psychoanalytic Study of the Child* 23: 264-300; 1968.

8. Friedman, Judith, and Pasnak, Robert. "Attainment of Classification and Seriation Concepts by Blind and Sighted Children." *Education of the Visually Handicapped* 5: 55-62; May 1973.

9. Guilford, J.P. "Three Faces of Intellect." *American Psychologist* 14: 303; 1946.

10. Gyr, John W., and Willey, Richmond L. "The Constructive Nature of Perceptual and Cognitive Processes and Its Implications for Cognitive Change." *Cognitive Studies, Vol. 2, Deficits in Cognition.* (Edited by J. Hellmuth.) New York: Brunner/Mazel, Inc., 1971. pp. 171-205.

11. Hampshire, Barry. "Language and Cognitive Development in the Blind Child." *Education of the Visually Handicapped* 9(4): 97-101; Winter 1977-78.

12. Harley, Randall K., Jr. "Children with Visual Disabilities." *Exceptional Children in the Schools, Special Education in Transition.* (Edited by Lloyd M. Dunn.) New York: Holt, Rinehart and Winston, Inc., 1973. pp. 410-464.

13. Hayes, Samuel P. *Contributions to a Psychology of Blindness.* New York: American Foundation for the Blind, Inc., 1941.

14. Higgins, Leslie C. *Classification in Congenitally Blind Children, An Examination of Inhelder and Piaget's Theory.* New York: American Foundation for the Blind, 1973.

15. Lawson, A.E., and Renner, J.W. "Relationships of Science Subject Matter with Developmental Levels of Learners." *Journal of Research in Science Teaching* 12(4): 347-358; 1975.

16. Lowenfeld, B. "The Blind Adolescent in a Seeing World." *Exceptional Children*, March 1959. pp. 310-315.

17. _____ . "Psychological Aspects of Blindness." *Outlook for the Blind and the Teachers Forum* 41(2): 31-36; 1947.

18. _____ . "Psychological Considerations." *The Visually Handicapped Child in School.* (Edited by B. Lowenfeld.) New York: The John Day Co., 1973.

19. Meighan, Thomas. *An Investigation of the Self Concept of Blind and Visually Handicapped Adolescents.* New York: American Foundation for the Blind, 1971.

20. Paton, D. "Some Psychological Considerations in Respect to Rehabilitation of the Blind." *Contemporary Ophthalmology: Honoring Sir Stewart Duke-Elder.* (Edited by J.G. Bellows.) Baltimore: The Williams and Wilkins Co., 1972.

21. Phillips, John L., Jr. *The Origins of Intellect: Piaget's Theory.* San Francisco: W.H. Freeman and Company, 1969.

22. Revesz, G. *Psychology and Art of the Blind.* (Translated by Dr. H.A. Wolff.) New York: Longmans, Green and Company, 1950.

23. Scott, Robert A. *The Making of Blind Men, A Study of Adult Socialization.* New York: Russell Sage Foundation, 1969.

24. Stephens, Beth. "Cognitive Processes in the Visually Impaired." *Education of the Visually Handicapped* 4: 106-111; December 1972.

25. Stephens, B.; Grube, C.; and Fitzgerald, J. *Cognitive Remediation of Blind Students.* Final Report. Richardson, Texas: The University of Texas at Dallas, 1977.

26. Stephens, B., and Simpkins, K. *The Reasoning, Moral Judgement, and Moral Conduct of the Congenitally Blind.* Final Report. Philadelphia: Temple University, 1974.

27. Wadsworth, Barry J. *Piaget's Theory of Cognitive Development, An Introduction for Students of Psychology and Education.* New York: David McKay Company, Inc., 1971.

19. CRITERION-REFERENCED TESTING AND PRESCRIPTIVE INSTRUCTION IN THE SCIENCE CLASSROOM

by Harry G. Lang

The author finds Public Law 94-142 to be a call for recognition of the usefulness of both criterion-referenced and norm-referenced evaluation methods in their most appropriate contexts. *Harry G. Lang is Assistant Professor of Physics, National Technical Institute for the Deaf, Rochester Institute of Technology, New York.*

One area needing much attention today is the evaluation of student needs (pretesting) and student achievement (posttesting). For many years educators have sorted out those students who are linguistically, culturally, physically, or otherwise experientially different. Placement of handicapped students in special education settings on the basis of such sorting procedures has resulted in a self-fulfilling prophecy. In effect, we label students as different and teach them to live with such a label. In many cases evaluation instruments used for such labeling and placement have undetermined reliability and validity.

Public Law 94-142, the Education for All Handicapped Children Act, mandates that evaluation of handicapped students be multifaceted and nondiscriminatory. Science teachers need to be sensitive to the linguistic and experiential lags of the handicapped learner. When developing a teacher-made test, a science instructor should evaluate whether the student's mastery of the course objectives is being fairly assessed, or whether verbally-loaded test items are discriminating against those with linguistic problems. The science teacher will have to decide whether good syntax should be a grading factor when lab reports indicate that the student has, indeed, fulfilled the content and process objectives of a laboratory experiment. Such decisions are largely subjective; yet, by-and-large they reflect the teacher's sensitivity to, and knowledge of, the special needs of handicapped students.

Over the past decade, a renewed emphasis on criterion-referenced tests for decision-making purposes in curriculum contexts has produced a vast literature. Many testing specialists contend that criterion-referenced tests may effectively enhance classroom evaluation of student learning through the identification of specific strengths and weaknesses of the students. The criterion-referenced test has an established congruence between test items and the domain of instructionally relevant objectives (i.e., the criterion). These tests purport to measure, as a consequence of this congruence, what the student knows (and does not know) with respect to course objectives, unlike norm-referenced tests, which measure individual differences in relation to a group.

A number of educators have recognized the potential of criterion-referenced tests for evaluating handicapped students. Norm-referenced testing procedures have frequently been found inadequate for the evaluation of handicapped students, even when special norms are established for these subgroups.

Criterion-referenced tests used effectively in the classroom may destroy the notion created through many years of normative-based measurement that for success or achievement to mean something, there must be available a reference group of nonattainers. If criterion skills are important, then educators should be concerned with whether or not each student has attained them, not with how many of the skills are attained in comparison to peers. Emphasis on this kind of test interpretation may lead to a new competitive ethic in the classroom, focusing on the achievement of each child through intra- rather than interindividual differences.

The mandated use of Individualized Education Programs (IEPs) by PL 94-142 has provided further rationale to explore the possible benefits of criterion-referenced measurement. IEPs must include both broad educational goals and short-term instructional objectives for each class in which the handicapped student is enrolled. Instruction must be prescribed on the basis of the individual learning needs of each handicapped student. This implies evaluation of instructional outcomes in terms of *goal attainment*, rather than relative standing in some group, and is highly compatible with the characteristics of criterion-referenced assessment.

Individualized Education Programs could very well bridge the gap between theory and practice. IEPs might also show that measurement and evaluation can be integral components of an adaptive instructional system. The diagnosis of individual needs through criterion-referenced pretesting, the prescription of instruction on the basis of this evaluation, and the determination of support

services necessary to overcome learning obstacles created by sensory, orthopedic, or mental impairment could contribute to the delivery services necessary for an appropriate education.

Criterion-referenced testing promises more utility for the science teacher who must identify specific learning needs. For those who use standard science curriculum materials, for example, or who have developed their own objectives-based instructional systems, criterion-referenced tests can assist in the diagnostic assessment of individual needs for prescriptive instruction purposes, progress monitoring, formative evaluation, or end-of-unit and end-of-term evaluation of mastery.

As the number of handicapped students mainstreamed into regular school programs increases, the development of criterion-referenced evaluation instruments should prove to be an asset in accommodating instructional practice to both handicapped and nonhandicapped children.

As M. Sapon-Shevin has pointed out, *all* children need appropriate educational planning, and to imply in any way that these are requirements only for handicapped students "is to perpetuate a senseless distinction, in this case at the expense of those students assigned to 'regular' education." (23, p. 120)

CRITERION-REFERENCED TESTING IN THE SCIENCE CLASSROOM

When evaluating the performance of students in the science classroom, criterion-referenced measurement has distinct advantages. Although little research has been done on criterion-referenced measurement in science curriculums for handicapped students, a number of contemporary science curriculums in regular school settings are utilizing criterion-referenced tests. W. Torop, for example, described the Individual Learning System in Chemistry (ILS Chem). (26) Primary, remedial, and enrichment materials include audio and visual tapes, films, conferences, text readings, and field experiences. Forty-two tutorial simulation modules are designed to supplement the individualized instruction. Criterion-referenced diagnostic tests are used to assign learning experiences appropriate for each student on the basis of performance on the tests. Comparable exams consisting of randomly selected, criterion-referenced test items are generated from a computer bank of over 2000 questions.

C.D. Dziuban and W.K. Esler described Science—A Process Approach (SAPA), a widely used science curriculum, as the most complete and extensively tested example of the use of criterion-referenced evaluation procedures in science. (5) R.R. Ludeman was involved in developing and comparing tests of science processes. His study utilized four subtests of the *SAPA Individual Competency Measures*, the Science Research Associates (SRA) test, and his own criterion-referenced test, *The Science Processes Test*. (12) It was concluded from Ludeman's study that the criterion-referenced method of test development is an appropriate approach to test construction, the criteria for "appropriateness" apparently being his method of item selection and the high correlations with the SAPA and SRA tests.

W.M. Gray applied both the criterion-referenced measurement theory and the developmental theory of Piaget to the assessment of human mental functioning. He writes that although the origins of the two theories are often regarded as mutually exclusive, they are, in fact, highly comparable in nature. (8) From an *ex post facto* analysis of Biological Science Curriculum Study test data, Gray has developed a framework for constructing science tests for criterion-referenced and Piagetian interpretations. (7) This includes an interesting approach to the examination of item difficulty from the perspective of developmental psychology.

Both criterion-referenced measurement and Piagetian theory share the general purpose of diagnosing behavior. Gray writes:

> CRM holds the promise of alleviating some of the undesirable practices of present-day testing; Piagetian theory delineates an approach to assessing and theorizing about mental processes that offers a viable alternative to the behavioristic approach currently in vogue. Every instructional or assessment situation involves the interaction of the student with some part of his world. If an assessment instrument does not take into account the way the student reasons about his world, it is highly doubtful that it can produce an adequate assessment of a person's competencies and of his efficiency in learning. . . . Piaget's developmental levels provide a very effective means of determining just how a child conceptualizes and interacts with his world, and would appear to provide a psychological basis for CRM that is consistent with the precepts of that system. (8, p. 245)

INDIVIDUALIZED EDUCATIONAL PLANNING

The evaluation of the achievement of handicapped students in mainstream settings has not yet been adequately investigated. The present thrust, in accordance with PL 94-142, is toward the use of Individualized Education Programs. IEPs require teachers to write objectives for every handicapped student in each instructional area. The lack of adequate details on evaluation procedures caused chaotic conditions during the first year that PL 94-142 was in effect, disillusioning many teachers, counselors, and resource personnel.

The law mandates that regular classroom teachers be

a part of each student's evaluation team. One clear interpretation of the law is that the evaluation process is not to be regarded in isolation from the education program.

The use of a well-defined domain of objectives may enable a science teacher to evaluate each student, whether handicapped or not, more efficiently for prescriptive instruction purposes. Criterion-referenced instruction may reduce the ambiguity regarding what kind of objectives should go into an IEP. A teacher should have little problem in finding guidelines for developing specific objectives for any science class. (See, for example, References 11, 17, and 19.)

Establishing passing scores for the tests will help counselors and resource personnel realize the expectations that a teacher has for all students. Teachers working closely with resource personnel may help the handicapped learner with individualized tutoring, if necessary, to increase learning and her/his prospects for successful performance on the criterion-referenced test.

The experiential deprivation of handicapped children very often results in lags that may be ameliorated through individualized instruction. When the handicapped student's special needs are identified, reinforcement may be provided. Defining objectives for a science class will provide direction to such reinforcement.

According to W. Hively, although norm-referenced testing is excellent for the purposes of selecting young people for employment or predicting future (relative) success in higher education, it is useless for the purpose of keeping "track of day-to-day progress and to study the conditions that facilitate or inhibit it." (10, p. 8)

A criterion-referenced diagnostic pretest may effectively indicate where along a continuum of structured or hierarchical science content an individual is performing and where further reinforcement via instruction and tutoring is necessary. Pretesting may also be helpful in evaluating gains in knowledge at various checkpoints throughout the course by comparing pretest performance with end-of-unit and end-of-course proficiency tests.

Criterion-referenced science tests administered at the end of instructional units may assist the teacher and the resource person in evaluating the appropriateness of both the IEP and the prescribed strategies and materials. When a student does not accomplish certain objectives as planned, the teacher and/or the resource person might be able to identify instructional materials or strategies that are not working well. The support services may not be adequate. The child may be having adjustment problems of a personal or social nature. Any number of reasons may contribute to unsatisfactory progress in the science class. Formative evaluation includes teacher/tutor observations and other methods of monitoring student progress. A multifaceted evaluation approach may enhance the accuracy of the decisions to revise the IEP. Criterion-referenced, end-of-unit mastery tests may provide a foundation for such multifaceted evaluation in terms of assessing achievement. Low scores on tests used for formative evaluation may be effective identifiers for further prescriptive action.

An adaptive educational environment can efficiently use criterion-referenced testing to assess generalizable behaviors that are reasonably teachable. But criterion-referenced tests might not be more useful than norm-referenced tests if certain conditions are not met. J. Rosner believes that the environment should attempt to modify students' aptitudes to enable them to benefit from the standard courses of instruction and/or alternative instructional activities that best accommodate a spectrum of individual needs. (22) If these conditions are not approximated, criterion-referenced diagnostic pretesting could have little use. In both instances described above, the aim is to optimize classroom performance for each student by providing circumstances suggested by the results of diagnostic testing. (6) This theory may apply well to the individualized educational planning delineated in PL 94-142.

PL 94-142 is, in effect, a call to further cognizance of the potential applications of the groundwork laid by R. Glaser, J. Rosner, J.S. Bruner, R.E. Snow, and their colleagues to enhance the learning of all students. It is a call for recognition of the usefulness of both criterion-referenced and norm-referenced evaluation methods in their most appropriate contexts. PL 94-142 is a mandate to provide appropriate educational opportunities to all handicapped students, something that has long been denied them. In this sense, the law is an attempt to merge theory and practice in restructuring the educational system.

REFERENCES

1. Bruner, J.S. *Toward a Theory of Instruction.* Cambridge, Mass.: Belknap, 1966.

2. Cronbach, L.J., and Snow, R.E. *Aptitudes and Instructional Methods: A Handbook for Research on Interactions.* New York: Irvington, 1977.

3. Cruickshank, D.R., and Kennedy, J.J. "The Institute for Research on Teaching: An Overview. *Journal of Teacher Education* 28(4): 44-49; 1977.

4. Deninger, M.; Cowan, N.; and Rosen, R. "IEP: Purpose, Contents, Participants, Processes." *PL 94-142 and Deaf Children.* Special Issue of the Gallaudet College Alumni Newsletter, 1976.

5. Dziuban, C.D., and Esler, W.K. "Criterion-referenced Tests: Some Advantages and Disadvantages for Science Instruction."*Science Education* 58(2): 171-174; 1974.

6. Glaser, R. "Individuals and Learning: The New Aptitudes." *Educational Researcher* 6: 5-13; 1972.

7. Gray, W.M. *Development of a Written Test Based on*

Item and Test Characteristics of Criterion-referenced Tests. ED 109 196. Final Report, University of Dayton, Project No. 2-E-052, Grant No. OEG-5-72-0044(509), National Center for Educational Research and Development, September 1973.

8. _____. "A Comparison of Piagetian Theory and Criterion-referenced Measurement." *Review of Educational Research* 48(2): 223-249; 1978.

9. Hambleton, R.K., and Novick, M.R. "Toward the Integration of Theory and Method for Criterion-referenced Tests." *Journal of Educational Measurement* 10: 159-170; 1973.

10. Hively, W., editor. *Domain-referenced Testing.* Englewood Cliffs, N.J.: Educational Technology Publications, 1974.

11. Hively, W., and others. "Domain-referenced Curriculum Evaluation: A Technical Handbook and a Case Study from the Minnemast Project." *CSE Monograph Series in Evaluation, No. 1.* Los Angeles: Center for the Study of Evaluation, University of California, 1973.

12. Ludeman, R.R. "Development of the Science Process Test (TSPT)." *Dissertation Abstracts International* 36(1): 203A; July 1975.

13. Moores, D.F. *Educating the Deaf: Psychology, Principles, and Practices.* Boston: Houghton Mifflin Company, 1978.

14. National Advisory Committee on the Handicapped. "Implementing the IEP Concept." *American Education* 13(7): 6-8; 1977.

15. Newell, A., and Simon, H.A. *Human Problem Solving.* Englewood Cliffs, N.J.: Prentice-Hall, 1972.

16. Peterson, P.L. *Interactive Effects of Student Anxiety, Achievement Orientation, and Teacher Behavior on Student Achievement and Attitude.* Unpublished doctoral dissertation. Stanford University, 1976.

17. Popham, W.J., and Baker, E.L. "Writing Tests Which Measure Objectives." *The Prentice-Hall Teacher Competency System.* Englewood Cliffs, N.J.: Prentice-Hall, 1973.

18. Porteus, A. *Teacher-centered vs. Student-centered Instruction: Interactions with Cognitive and Motivational Aptitudes.* Unpublished doctoral dissertation. Stanford University, 1976.

19. Price, J.R.; Martuza, V.R.; and Crouse, J.H. "Construct Validity of Test Items Measuring Acquisition of Information from Line Graphs." *Journal of Educational Psychology* 66(1): 152-156; 1974.

20. Reynolds, M.C. "Trends in Special Education: Implications for Measurement." *Domain-referenced Testing in Special Education.* (Edited by W. Hively and M.C. Reynolds.) Reston, Va.: Council for Exceptional Children, 1975.

21. Rosen, R.; Skinski, E.; and Pimental, A. "PL 94-142: An Analysis of Its Evolution, Features and Implications." *PL 94-142 and Deaf Children.* Special Issue of the Gallaudet College Alumni Newsletter, 1976.

22. Rosner, J. "Testing for Teaching in an Adaptive Educational Environment." *Domain-referenced Testing in Special Education.* (Edited by W. Hively and M.C. Reynolds.) Reston, Va.: Council for Exceptional Children, 1975.

23. Sapon-Shevin, M. "Another Look at Mainstreaming: Exceptionality, Normality, and the Nature of Difference." *Phi Delta Kappan* 60(2): 119-121; 1978.

24. Snow, R.E. *Theory and Method for Research on Aptitude Processes: A Prospectus.* Technical Report #2, Aptitude Research Project. Stanford, Calif.: School of Education, Stanford University, 1976.

25. _____. "Individual Differences and Instructional Theory." *Educational Researcher* 6(19): 11-15; 1977.

26. Torop, W. "An Analysis of Individualized Learning System Chemistry." *Journal of College Science Teaching* 8(2): 114-116; 1978.

27. Tyler, R.W. "Testing for Accountability." *Educational and Psychological Measurement: Contributions to Theory and Practice.* (Edited by D.A. Payne and R.F. McMorris.) Morristown, N.J.: General Learning Press, 1975.

NEA Resolution adopted by the NEA Representative Assembly

B-25. Education for All Handicapped Children

The National Education Association supports a free, appropriate public education for all handicapped students in a least restrictive environment, which is determined by maximum teacher involvement. However, the Association recognizes that to implement Public Law 94-142 effectively—

a. The educational environment, using appropriate instructional materials, support services, and pupil personnel services, must match the learning needs of both the handicapped and the nonhandicapped student.
b. Regular and special education teachers, pupil personnel staff, administrators, and parents must share in planning and implementing programs for the handicapped.
c. All staff must be adequately prepared for their roles through in-service training.
d. The appropriateness of educational methods, materials, and supportive services must be determined in cooperation with classroom teachers.
e. The classroom teacher(s) must have an appeal procedure regarding the implementation of the individualized education program, especially in terms of student placement.
f. Modifications must be made in class size, using a weighted formula, scheduling, and curriculum design to accommodate the demands of each individualized education program.
g. There must be a systematic evaluation and reporting of program developments using a plan that recognizes individual differences.
h. Adequate funding must be provided and then used exclusively for handicapped students.
i. The classroom teacher(s), both regular and special education, must have a major role in determining individual education programs.
j. Adequate released time or funded additional time must be made available for teachers so that they can carry out the increased demands placed upon them by P.L. 94-142.
k. Staff must not be reduced.
l. Additional benefits negotiated for handicapped students through local collective bargaining agreements must be honored.
m. Communications must be maintained among all involved parties.
n. All teachers must be accorded by law the right of dissent concerning each individualized education program, including the right to have the dissenting opinion recorded.
o. Individualized education programs should not be used as criteria for the evaluation of teachers.
p. Teachers, as mandated by law, must be appointed to state advisory bodies on special education.
q. Teachers must be allowed to take part in the U.S. Office of Special Education and Rehabilitative Services on-site visits to states. Teachers should be invited to these meetings.
r. Incentives for teacher participation in in-service activities should, as mandated by law, be made available for teachers.
s. Local associations must be involved in monitoring school systems' compliance with P.L. 94-142.
t. Student placement must be based on individual needs rather than space availability. (78, 80)

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